FARM MACHINERY
AND EQUIPMENT

FARM MACHINERY AND EQUIPMENT

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Fifth Edition

TATA McGRAW-HILL PUBLISHING COMPANY LTD.
BOMBAY — NEW DELHI

FARM MACHINERY AND EQUIPMENT

T M H Edition

Printed in India by arrangement with McGraw-Hill, Inc.
New York.

This book has been published with the assistance of the Joint Indian American Textbook Programme.

18.75

Published by Tata McGraw-Hill Publishing Company Limited and
Printed by Mohan Makhijani at Rekha Printers, New Delhi-15

PREFACE

Machines used in the production and processing of crops grown for food and fiber are constantly changing. New developments and improvements in farm equipment and new technology in farming practices have reduced farm labor requirements. Machines become obsolete and uneconomical within a few years. These factors make it necessary to revise and bring up-to-date developments and improvements in the various types of farm equipment in current use on the farm.

In the fifth edition of *Farm Machinery and Equipment* the author discusses the latest developments in farm power equipment. New developments in minimum tillage, planting, weed control, and hay and forage harvesting are presented. Equipment for the application of insecticides, herbicides, and fungicides is described. Harvesting equipment for cotton, small grain, corn, and several new crops is discussed in considerable detail. Several of the chapters have been divided and rearranged for a more adequate presentation. A new chapter has been added on the economics and management of farm equipment. An effort has been made to present the latest information about equipment used on the farm that has proved to be economical in use and instrumental in reducing the cost of crop production.

The author wishes to express his appreciation to the many farm-machinery manufacturers for their cooperation in furnishing trade literature and illustrative material. Without their aid it would not have been possible to prepare a manuscript covering the various types of farm machines. Thanks are due Professor William H. Alred of the Department of Agricultural Engineering of Texas A & M University for reading the manuscript and for his suggestions, and to Professor Felix E. Edwards of Mississippi State University for his suggestions. Thanks are also due Professor J. W. Sorenson Jr. of the Department of Agricultural Engineering of Texas A & M University for reviewing the chapter on crop-processing equipment, and to Professor V. W. Edmonson of the Department of Agricultural Economics and Sociology of Texas A & M University for reviewing the chapter on economics and management.

Appreciation is expressed to the instructors in farm-machinery courses in many states for their helpful letters. Special appreciation is extended to Mrs. Marjorie Morris for her help in typing the material for the third, fourth, and fifth editions of this book. A sincere effort has been made to give credit wherever due, and any oversight was not intentional.

Harris Pearson Smith

CONTENTS

FARM MACHINERY AND ITS RELATION TO AGRICULTURE

1

In the beginning, all crops for the sustenance of mankind were produced and prepared by the power of human muscles. Many centuries passed before the power of animal muscles was used to relieve that of the human being. With the discovery of iron, tools were fashioned that further relieved the labor of human muscles. The transition from hand farming to this modern power-farming age was at first slow, but with the development of the steel plow, the internal-combustion engine, the farm tractor, and other modern farm machines, the movement has accelerated beyond the wildest dreams of our forefathers. The changes which occurred in the past two decades have so tremendously affected human values that one wonders what effect farm machines of the future will have on our welfare. In fact, there has been more farming progress in the last hundred years than in all the previous history of the world.[1]

Progress of Farm Mechanization. In 1855, practically 80 per cent of the population of the United States lived on farms, while in 1963, more than 85 per cent lived in towns and cities.

Figure 1-1 shows that

> . . . since the peak of farm population in 1916, the trend in the number of persons living on farms has been generally downward. The depression in the 1930's brought a temporary increase, but World War II

[1] *Agr. Engin.*, 34(2):91, 1953; *Life*, 34(1):62, 1953; 38(1):54, 1955.

with its demand for manpower in industry and the armed forces caused a rapid loss in the farm population. The high level of nonfarm employment prevailing since 1916, together with defense mobilization following the outbreak of hostilities in Korea, have been conducive to a continuation of a relatively high rate of net migration from farms.[2]

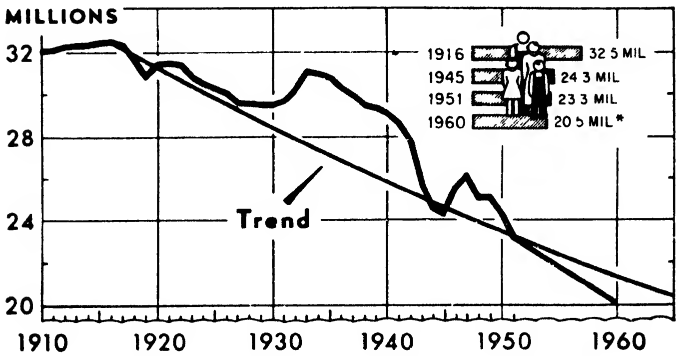

Fig. 1-1. Decline in farm population, 1910–1960.

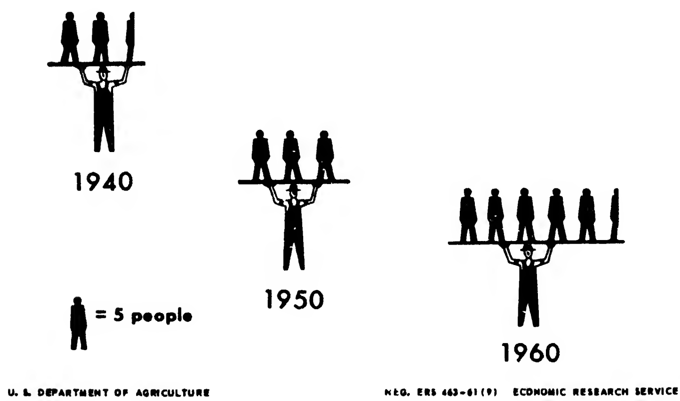

Fig. 1-2. Fewer farm workers support more people by the use of new developments and improvements in farm machinery.

In 1854, farm tools were so crude that each farm worker could produce only enough food for himself and four to five others. By 1920, with improved horse-drawn equipment, the farm worker could support himself and nine others. In 1955, with modern power equipment, the farm worker could support himself and about seventeen others. By 1963 it is estimated that one farm worker could produce enough food and fiber to support himself and about thirty others (Fig. 1-2).

[2] *U.S. Dept. Agr., BAE.*

A key part of the technological revolution under way in agriculture, and largely a product of it, has been the rapid increase in output per man-hour of labor on farms. Output per man-hour is now the greatest in history. The period from 1945 to 1962 has had rapid progress in farm mechanization and sharp increases in yields of crops and livestock because of widespread adoption of improved farming practices. These changes have made possible a great rise in total farm output, with fewer man-hours spent at farm work.

Power Equipment Cuts Production Man-hours. The effect of the mechanization of agriculture is shown in the number of man-hours required to grow and harvest an acre of wheat yielding 20 bushels. In 1830, when the grain was sown by hand and harvested by hand with a cradle, 55.7 man-hours were required. In 1896, with the use of a horse-drawn drill and binder, 8.8 man-hours were required, while in 1930, with the tractor-drawn drill and combine, only 3.3 man-hours were necessary.[3] Newer machines and improved practices in producing spring wheat reduced the required man-hours in 1950 to 1.4 in South Dakota and to 1.8 in northeastern Montana and southwestern North Dakota. Where summer fallow was practiced, the man-hour requirement per acre was 1.9 in western South Dakota and 2.6 in the central areas of the Dakotas. The per-acre tractor-hours for these areas were 0.8, 1.4, 1.5, and 1.8, respectively. The difference in man- and tractor-hours results from the use of self-propelled combines and hauling where no tractors were used. Improved machines and practices have brought about similar reductions in man-hour requirement in the production and harvesting of most field crops, in the relation of farm output to labor input (Fig. 1-3).

There has been more progress in the reduction of man-hours required to grow and harvest an acre of cotton from 1940 to 1960 than in all the previous history of the crop. This resulted from farm-mechanization practices.

Equipment Must Suit the Crops and the Types of Farming. The two major crop systems in the United States are *row crops* and *broadcast crops.* The principal row crops are corn, cotton, potatoes, tobacco, and truck crops. Hay, rice, wheat, and the small grains are broadcast crops. Farm machinery can be profitably used with both systems, but the more uses to which a machine can be adapted, the less the initial investment in equipment. Certain types of plows and harrows for seedbed preparation have a wide application. Grain drills and combines are adapted for seeding and harvesting of wheat and the small grains, and the combine can also be used for harvesting some row crops, such as sorghum grain and soybeans.

[3] *U.S. Dept. Agr. Misc. Rpt.* 157, 1933.

[4] *U.S. Dept. Agr., BAE,* F. M. 92, Section 4, 1953.

Breeding Crops to Suit Machinery. Certain field crops do not readily lend themselves to machine harvesting. The drooping heads of some varieties of grain sorghum make it difficult to head them without cutting excessively long stems. Plant breeders have now developed varieties of sorghum with straight, erect heads of uniform height that are well adapted to combining. As cotton matures, it produces long vegetative and fruiting branches with an abundance of foliage, which make it difficult to harvest the cotton bolls with machinery. Plant breeders, however, have recently developed types of cotton plants that are more suit-

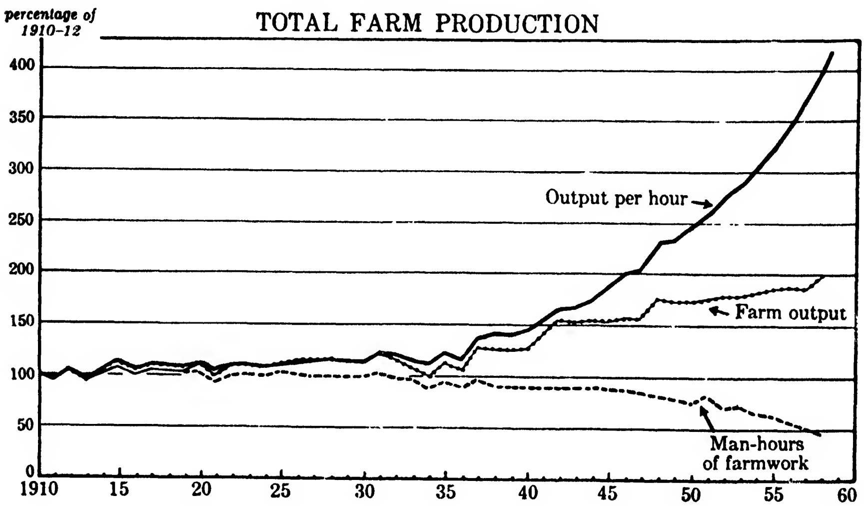

Fig. 1-3. Efficiency in the use of farm labor.

able to machine harvesting. Fluffy types are suitable for the picker, and nonfluffy or stormproof types are best harvested by the stripper.

Trend toward Tractor-mounted, Pickup, and Quick-change Units. When the tractor was first used for the operation of field equipment, all machines were pulled behind the tractor. Specially designed planters and cultivators were mounted on row-crop tractors about 1930. With the development of the power take-off, other machines, such as mowers and corn pickers, were fitted to and mounted on the tractor. These first tractor-mounted units required considerable labor and time to mount and dismount. They were put together practically piece by piece and taken off in a similar manner. All lifting and adjusting was done by hand levers. Later, units were developed that could be attached as assembled units and lifted with mechanical power lifts. Two- and three-bottom plows were at first considered too heavy to be picked up or lifted as units. In 1955, however, three-bottom moldboard plows, tandem disk harrows, and many other formerly trailing machines were picked up, while mak-

ing turns, by means of hydraulic power. Consequently, most farm equipment for cultural purposes is now designed for tractor attachment. The exceptions are self-propelled combines, corn pickers, and cotton pickers.

Farm Management. Farm machines designed for higher speeds, constructed of heat-treated steels, and equipped with more durable bearings will lessen operating time and will lower costs. Terracing and contouring of fields will cause changes in farming practices, both in the types of machinery used and in cropping systems. These and various other factors will materially affect the management of farm labor and equipment.

See Chap. 26 for a complete discussion of the management of farm equipment.

Rubber Tires for Farm Equipment. When the first edition of *Farm Machinery and Equipment* was published in 1929, there were no farm machines equipped with rubber tires. In the second edition in 1937, only a few machines equipped with rubber tires were shown. The third edition in 1948 showed rubber tires on most equipment. The fourth edition in 1955 and the fifth edition in 1964 show all field equipment mounted on pneumatic rubber tires.

The various factors related to the types and use of rubber tires are given in Chap. 8.

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Anderson, K. W.: New Horizons in Farm Machinery Development, *Agr. Engin.*, 33(12):765, 1953.

QUESTIONS AND PROBLEMS

1. Discuss the development and progress of farm mechanization.
2. Explain how power equipment reduces man-hours in crop production.
3. Enumerate machines that can be used in producing two or more crops. List some machines that have a single use.
4. Trace the trend in the development of tractor-mounted and quick-change units.

MATERIALS OF CONSTRUCTION

2

The strength, durability, and service of a farm implement depend largely upon the kind and quality of material used in building it. There is a tendency in the construction of implements to eliminate as many castings as possible and to use pressed and stamped steel. Where this is done, the cost of manufacturing machinery in quantities is materially reduced. The weight of the machine is reduced, but the strength and durability are retained and often improved. The success or failure of an implement frequently depends upon the material used in building it.

The materials used in the construction of farm equipment may be classified as *metallic* and *nonmetallic*. The metallic is further divided into ferrous and nonferrous materials.

NONMETALLIC MATERIALS

The nonmetallic materials are wood, rubber, leather, vegetable fibers, and plastics.

Wood. Iron and steel have practically taken the place of wood. There are, perhaps, two reasons for this: first, steel is more durable; second, it is becoming cheaper than good wood because of the scarcity of the latter.

Rubber. Rubber is both derived from the gum of trees and made synthetically. Special compositions of rubber are developed to obtain the properties desired for a particular application. Design engineers should have a thorough knowledge of the properties of rubber—both natural and synthetic. There are several grades of rubber materials varying in

the general properties of hardness, flexibility, bonding properties, and chemical resistance. The leading use of rubber on farm equipment is in production of implement tires and tubes. Much rubber is also used in making flat and V belts and for the insulation of ignition wires. Rubber bushings on suspended oscillating components often give an excellent service life and require no lubrication. Disks of rubber to clasp plants are used on transplanters.

Plastics. A plastic material is an organic solid, polymerized to a high molecular weight, that is capable of being molded, usually with the aid of heat or pressure or both. There are many groups and types of commercially available plastics. These are sold under many trade names. Certain types of plastics are used for plow moldboards, handles, instrument parts, bearings, washers, tubing, battery cases, bristles for brushes, seed and fertilizer hoppers, and windows. An experimental machine has been developed for the laying of sheets of polyethylene as a mulch.

Leather and Vegetable Fibers. Leather is largely a belting material. Vegetable fibers are used in brushes, fabrics, and upholstery padding.

NONFERROUS METALS

The nonferrous metals are copper and its alloys (such as brass and bronze), aluminum, magnesium, lead, zinc, and tin.

Alloy. An alloy is a substance that has metallic properties and is composed of two or more chemical elements of which at least one is a metal. The number of possible alloys is infinite. They are made by the fusion of metals. The most common groups of alloys are bronze, brass, babbitt, alloy steels, and the aluminum alloys.

Copper. In commercial importance, copper ranks next to iron and steel because of its electrical conductivity and its capacity to form useful alloys. Copper is soft enough to be rolled or hammered into thin sheets or drawn into fine wire. It is used for ignition and instrument wires on engines, in tubing for conducting fuel from tank to carburetor, and in generator and starting motors.

Brass. Ordinary brass is an alloy of copper and zinc. Some commercial brasses contain small percentages of lead, tin, and iron. The percentage of copper in brass may range from 60 to 90 per cent, and the percentage of zinc from 10 to 40 per cent. Brass is used for making radiators, pipe, welding rods, screens for fuel lines, instrument parts, and fittings.

Bronze. Bronze is an alloy of copper and tin. However, zinc is sometimes added to cheapen the alloy or change its color and increase its malleability. The amount of tin in bronze may vary from 5 to 20 per cent. Phosphor bronze, manganese bronze, and aluminum bronze are special copper alloys containing small percentages of tin, zinc, and other metals such

as phosphorus, manganese, or aluminum. These are used for bearing bushings, springs, pipe fittings, valves, pump pistons, and bearings.

Babbitt. Babbitt is a tin-base alloy containing small amounts of copper and antimony. Good babbitt for automobile bearings should contain 7 per cent copper, 9 per cent antimony, and 84 per cent tin. It is used mostly as a bearing metal.

Solder. Common solder contains about one part tin and one part lead. Hard plumbers' solder contains two parts tin and one part lead. Solder is used extensively in joining brass, copper, tin, steel, and cast iron.

Bearing Metals. White metals and bronze alloys are most frequently used for machine bearings, but wood, glass, plastics, rubber, and other materials are also used.

Aluminum. This is a white metal with a bluish tinge. It has a specific gravity of 2.7 and a melting point of 658.7°C. and is resistant to corrosion and to many chemicals. It, however, can be dissolved by alkalies and hydrochloric acid. It is frequently alloyed with iron and copper. Aluminum is extensively used to make light castings for certain types of farm equipment.

Zinc. Zinc is a bluish-white, crystalline, metallic element, brittle when cold, malleable at 110 to 210°C. It is used mostly as a coating on sheet iron and die castings as a protection against corrosion.

FERROUS METALS

The ferrous metals are iron and its various alloys, such as cast iron, malleable cast iron, wrought iron, and steel. There are many others. The best way of forming parts of irregular shape from the ferrous metals is by making a pattern and pouring molten metal into a mold. These are known as *castings*.

Cast Iron. Cast iron is iron containing so much carbon or its equivalent that it is not usefully malleable at any temperature. The amount of carbon varies from 2.2 to 4.3 per cent, depending on the amount of silicon, sulfur, phosphorus, and manganese also present.

There are two grades of cast iron: *gray cast iron*, in which the carbon is segregated from the iron in the form of graphite, and *white cast iron*, which has carbon and iron combined. Another grade is often mentioned, *mottled cast iron*, which is a mixture of the gray and white. Cast iron is made by combining pig iron and scrap iron and pouring the molten metal into sand molds of the desired shape, where it is allowed to cool. Then it is cleaned and made ready for use.

Cast-iron castings are generally large, bulky, and very brittle. They cannot be hammered to any great extent without breaking. They cannot be forged but can be cemented together by brazing or welding. The

brazing process consists of heating the broken parts to a welding heat and applying a brazing compound. Welding is the process of fusing two pieces by heating them with an oxyacetylene-gas flame and applying the proper rod.

Malleable Cast Iron. Malleable iron is annealed white cast iron in which the carbon has been separated from the iron without forming flakes or graphite, as in gray cast iron. It will bend to a limited extent without breaking.

The process of making malleable cast iron consists of melting the white pig iron, with scrap, in the furnace and pouring it rapidly into sand molds while very hot. After cooling, the castings are cleaned and made ready for annealing. The annealing pots are usually of cast iron. The castings are packed in these pots along with iron scale (iron oxide), which acts as a decarburizer and causes much of the brittle quality to disappear. The annealing pots containing the castings and iron scale are placed in an oven, and the temperature is raised to a cherry-red heat, about 1450°F., and held there for from 3 to 5 days, depending on the size of the castings and the amount of decarbonizing desired. Then the furnace is allowed to cool slowly for a few days before the castings are removed and cleaned. Malleable cast iron is used extensively in building farm machinery and for various kinds of hardware.

Chilled Cast Iron. Chilled cast iron is cast iron poured into molds that have a part of the mold made of metal instead of sand. This metal causes the molten iron that comes in contact with it to cool more rapidly than the balance of the casting, thus forming a hard surface. The metal portion of the mold must be heated to a temperature of about 350°F. before pouring to prevent explosions when the hot metal strikes the cold. Chilled-cast-iron moldboards for plow bottoms show that the iron fibers are brought perpendicular to the surface in the areas where the metal is chilled.

Ductile Cast Iron. This is a new metal for farm-equipment parts. Patents were granted on the process of producing ductile cast iron in 1949. It is a high-grade iron produced by the ladle addition of magnesium alloy to molten iron prepared to produce gray cast iron. The magnesium acts as a desulfurizer, and when added in controlled amounts, it produces spheroidal carbon instead of flake carbon (graphite).

Ductile cast iron has many applications in farm equipment, such as sprockets, gears, chilled plowshares, mower guards, parts for hay-baler knotter mechanism, and tail-wheel mounting brackets for plows.

Ductile cast iron can be welded similarly to gray cast iron. It requires, however, a special reverse-polarity arc rod designated as *Ni-rod* 55. This rod deposits a bead with 8 per cent elongation and with tensile properties of over 60,000 pounds per square inch.

Cast Steel. Cast steel is a steel that is cast. It can be made in varying degrees of hardness and is more durable than the best grade of cast iron. It is used mostly in gearing. Not much of it is found in agricultural machinery.

Wrought Iron. Wrought iron is nearly pure iron, with some slag, and is used in forge work, as it is readily welded and easy to work. Wrought iron has very little carbon in it, ranging from 0.05 to 0.10 of 1 per cent. It is expensive, however, and a mild steel is used to a considerable extent in place of it. The commercial form is obtained by rolling the hot iron into bars or plates from which nails, bolts, nuts, wire, chains, and many other products are made.

Kinds of Steel. Steel is a variety of iron classed between cast iron and wrought iron, very tough, and, when tempered, hard and elastic. The hardness of steel is determined principally by its carbon content but is influenced by the percentages of manganese, phosphorus, and sulfur it also contains. The composition of the various grades of carbon, manganese, nickel, molybdenum, chromium, chromium-vanadium, and tungsten steel is identified by a numbering system as follows:

TABLE 2-1. CARBON CONTENT AND NUMBER OF DIFFERENT KINDS OF STEEL

Type of steel	Percentage of carbon	Number
Very low carbon	0.05–0.18	1008–1016
Low carbon	0.19–0.23	1017–1022
Medium carbon	0.24–0.47	1025–1043
High carbon	0.48–0.70	1045–1065
Very high carbon	0.71–1.03	1070–1095

The last two digits in the number indicate the hardness of the steel. Steels with small amounts of carbon are used in making items that are easily cut and shaped. High-carbon steel is used in making tools, thread dies, ball and roller bearings, and items that will cut the low-carbon steels. Strength is closely related to the carbon content and the degree of hardness. Copper-bearing steels and the various alloys have numbers ranging above non-copper-bearing steels.

Color schemes are used as marks of identification for various kinds of steel when stored in warehouses.

Steel Alloys. A steel alloy is a mixture of two or more metals. The mixture is composed largely of steel with small amounts of one or more alloy metals. The more common alloy elements used in steel are boron, manganese, nickel, vanadium, tungsten, and chromium.

Boron Steel. *This contains a small amount of boron. The boron acts to* increase the hardening ability of the steel, that is, its ability to harden deeply when heat-treated by quenching and tempering. It is used for axle shafts, wheel spindles, steering-knuckle arms, cap screws, and studs.

Manganese Steel. This usually contains 11 to 14 per cent manganese and from 0.8 to 1.5 per cent carbon and has properties of extreme hardness and ductility. It is usually cast for the desired shape and finished by grinding. It is used in feed grinders and machine parts subject to severe wear.

Nickel Steel. Steel containing from 2 to 5 per cent nickel and from 0.10 to 0.50 per cent carbon is strong, tough, and ductile. Nickel steels are used in making parts that are subjected to repeated shocks and stresses.

Vanadium Steel. When less than 0.20 per cent vanadium is added to steel, the resulting alloy is given additional tensile strength and elasticity comparable to the low- and medium-carbon steels with a corresponding loss of ductility.

Chrome-Vanadium Steels. These contain about 0.5 to 1.5 per cent chromium, 0.15 to 0.30 per cent vanadium, and 0.15 to 1.10 per cent carbon. These steels are used extensively in making machinery castings, forgings, springs, shafting, gears, and pins.

Tungsten Steel. Steels containing from 3 to 18 per cent tungsten and from 0.2 to 1.5 per cent carbon are used for dies and high-speed cutting tools.

Molybdenum Steel. This steel has properties similar to tungsten steel.

Chrome Steel. Chrome steels usually contain from 0.50 to 2.0 per cent chromium and from 0.10 to 1.50 per cent carbon. Chromium steels are used in making high-grade balls, rollers, and races for ball and roller bearings. Chrome steels containing from 14 to 18 per cent chromium produce a variety of stainless steel.

Chrome-Nickel Steel. The average chrome-nickel steel contains about 0.30 to 2.0 per cent chromium, from 1.0 to 4.0 per cent nickel, and from 0.10 to 0.60 per cent carbon. Heat-treatment increases its tensile strength, elasticity, and endurance limits. It is tough and ductile. Chrome-nickel steel is used in making gears, forgings, crankshafts, connecting rods, and machine parts.

When chrome-nickel steel contains from 16 to 19 per cent chromium, 7 to 10 per cent nickel, and less than 0.15 per cent carbon, it is generally called *stainless steel*. The commonly called 18-8 *stainless* falls in this group.

Tool Steel. The term *tool steel* is used in designating a high-carbon steel that is used for making tools. It has the property of becoming extremely hard by quenching from a temperature of 1400 to 1800°F. It can then be

treated to obtain any degree of hardness by heating at lower temperatures.

Soft-center Steel. Soft-center steel consists of three layers of steel, as shown in Fig. 2-1. Two layers of hard steel are placed on each side and welded to an inner layer of soft steel. In this manner, a hard surface is obtained, without brittleness. Soft-center steel is used in the making of plow bottoms. Filing a slight notch in the edge of the metal will reveal the three layers.

Clad steels or *bimetal* steels are made by permanently bonding a layer of nickel, inconel, or monel metal to a heavier base layer of steel by hot

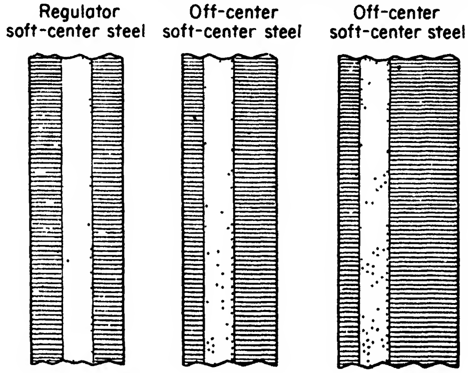

Fig. 2-1. Different types of soft-center steel.

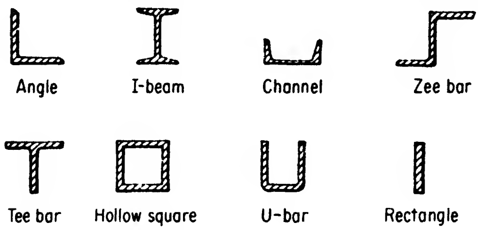

Fig. 2-2. Types of structural steel.

rolling. The cladding layer may range in thickness from $\frac{3}{16}$ inch up, with the cladding amounting to about 10 to 20 per cent of the total plate thickness.

Shapes of Steel. Steel that is formed into angles, channels, tee bars, I beams, Z bars, U bars, and hollow squares, as shown in Fig. 2-2, is known as structural steel. Solid bars are furnished in many shapes, such as round, half-round, oval, half-oval, square, hexagon, and flat-rectangle strips. Various sizes of round and square tubing are available. Many special parts are formed from flat-rolled carbon steel and stainless sheets and plates. A few of these shapes are shown in Fig. 2-3.

Hardening of Finished Steels. In many cases where long-life service is desired, extremely hard steels cannot be forged and machined to the required shape and finish. Under these conditions a softer steel is shaped and finished, then given a hardening treatment. The most common hardening processes are casehardening and hardening by heat-treatment.

Casehardening. This is a process of hardening a ferrous alloy so that the surface layer or case is made substantially harder than the interior or

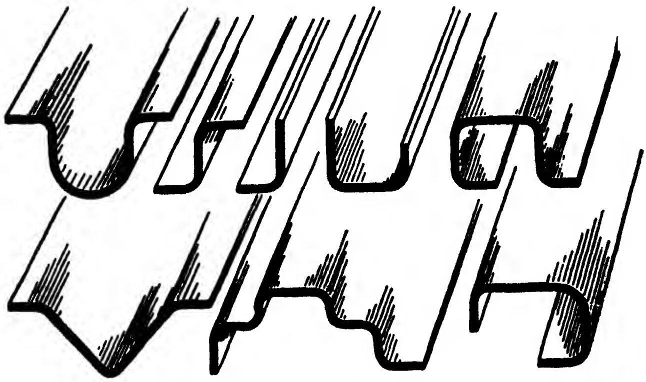

Fig. 2-3. Sheet metal can be pressed into many shapes.

core (Fig. 2-4). Casehardening can be done by several processes, such as carburizing and quenching, carbonitriding, nitriding, cyaniding, induction hardening, and flame hardening.

Carburizing is a process in which steel is packed in charred peach pits or charcoal and heated at about 1600°F. for a long enough period to give the desired depth of hardness. It is then removed, quenched, and tempered to give the desired hardness.

Fig. 2-4. Casehardened steel.

Nitriding is a process of casehardening by placing the finished heat-treated steel in an airtight box and heating to 1000°F. as ammonia gas is injected into the chamber.

Carbonitriding is a process of hardening steel by the addition of a carbon-rich gas as well as ammonia.

Cyaniding is a process where the steel is dipped into a molten bath of potassium cyanide for a short time. Some carbon and nitrogen are ab-

sorbed by the steel, which results in the hardening of a thin surface layer.

Induction hardening is accomplished by the use of a high-frequency alternating electric current for a short period. A current is induced on the surface of the steel, which causes localized heating. After heating, the surface is flooded with water to quench and harden it.

Flame hardening is a process in which an oxyacetylene torch is used to heat the surface quickly to a temperature above the critical temperature, after which the surface is quenched with water.

Hardening by Heat-treatment. *Heat-treatment* is a term used to describe the application of heating and cooling processes to steel, through a range of temperatures, to improve the structure and produce desirable characteristics. Such treatments include annealing, hardening, tempering, and casehardening.

Plow beams, plow disks, and disk-harrow blades are examples of parts of agricultural machines that are heat-treated in order to make more serviceable implements.

Hard Facing or Surfacing. The application of a hard surface, or face, by welding is not to be confused with the hardening of finished surfaces. *Hard facing*, or surfacing by welding, is the addition of a hard metal over the base metal by applying a welding-rod deposit to provide a final surface that is harder than the original surface.

Hard facings are applied to parts for wear resistance, heat resistance, corrosion resistance, or combinations of the three. Most hard facing is done to prevent wear. In hard-facing parts, it is essential that the correct hardening material be selected to suit the base metal.

There are possibly hundreds of different hard-facing alloys available, and these are manufactured in three forms: as welding rods, as insert shapes, and in powdered forms. There are many types of welding rods. The rods used with the oxyacetylene torch are not coated. They are heated and dipped into a special flux. Electric rods usually have a flux coating.

Inserts and filler bars are welded on surfaces where extra-heavy hard facing is required.

Hard-facing powders are spread over the base metal, which is heated to the melting point to embed the powders firmly.

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QUESTIONS AND PROBLEMS

1. Classify and give examples of construction materials.
2. Discuss the various nonmetallic materials and give uses of each.
3. Discuss the use of plastics in farm equipment.
4. Name the nonferrous metals and give uses of each.
5. Define an alloy.
6. What are the ferrous metals?
7. Explain the differences in the various types of castings.
8. How is malleable cast iron produced?
9. Discuss the influence of carbon content on the hardness of steel.
10. Discuss the differences in structure and metals, in soft-center steel and in the clad steels.
11. Describe the various methods of hardening finished steels.
12. Discuss hard facing of metals.
13. Name the common steel alloys and their uses.
14. What is stainless steel?

MECHANICS

3

A clear conception of the fundamental principles of mechanics, as well as of their practical application to machinery, is necessary to a comprehensive study of farm machinery.

Force. *Mechanics* is the science that treats of forces and their effect. *Force* is the action of one body upon another which tends to produce or destroy motion in the body acted upon. Force may vary in magnitude and in method of application. In general, force is associated with muscular exertion. This, however, does not completely cover the scope and action of force, because flow of an electric current, freezing of a liquid, and ignition of explosives may exert a certain amount of force. In order to compare different forces, they must all be in terms of the same unit. One such unit is called the *pound weight.*

Work. Whenever a force is exerted to the extent that motion is produced, work is performed. Work is measured by the product of the force times the distance moved, and it can be expressed in several combinations of units of weight (force) and distance, as inch-pounds, foot-pounds, and foot-tons. A foot-pound of work is done when a body is moved 1 foot against a force of 1-pound weight. The amount of work required to place a 100-pound bag of grain on a wagon that has a box 4 feet from the ground can be determined by multiplying the weight, 100 pounds, by the height, 4 feet, which will equal 400 foot-pounds of work done to place the bag of grain upon the wagon, or

$$\text{Work} = \text{force} \times \text{distance}$$

or

$$W = F \times D$$
$$W = 100 \times 4 = 400 \text{ ft.-lb. of work}$$

If a force moves in a circular direction to give a twisting action, this rotating force is termed *torque*. For example, a belt which exerts a force to turn a pulley and thus transmits power through a shaft gives the shaft a twisting action or a torque force. The pull on the belt in pounds multiplied by the radius of the pulley equals the torque in foot-pounds or, rather, pound-feet.

A force which produces the same effect upon a body as two or more forces acting together is called their *resultant*. The separate forces which can be so combined are called *components*. The finding of the resultant of two or more forces is called the *composition* of forces. The finding of two or more components of a given force is called the *resolution* of the force.

The *moment* of a force with respect to a point is the product of the force multiplied by the perpendicular distance from the given point to the direction of the force. In Fig. 3-1, the moment of the force *P* with relation to the point *A* is *P* times *AB*. The perpendicular distance is called the *lever arm* of the force. The moment is a measure of the tendency of the force to produce rotation about the given point, which is termed the *center of moments*. If the force is measured in pounds and the distance in inches, the moment is expressed in pound-inches, if measured in pounds and feet, the expression would be pound-feet. If *P* is a force of 10 pounds and 20 inches from *A*, its moment about *A* is 200 pound-inches.

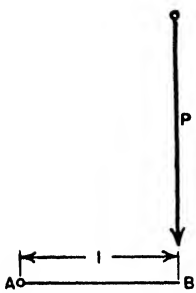

Fig. 3-1. The moment of forces.

Power. Power is the rate of doing work. To determine the power used or transmitted by a machine, the force must be measured, also the distance through which the force acts and the length of time required for the force to act through this distance. The units of power ordinarily used in America are the *foot-pound per second*, the *foot-pound per minute*, and the *horsepower*.

If a body is moved 1 foot per second against a force of 1-pound weight, the rate of work is 1 foot-pound per second. If it moves 1 foot per minute against the same force, the rate is 1 foot-pound per minute. If it moves so that 33,000 foot-pounds are done each minute, the rate is 1 horsepower. The horsepower is based on the rate at which a 1,500-pound horse can do work. If such a horse pulls 150 pounds, 10 per cent of its weight, and moves at the rate of 220 feet per minute, or 2½ m.p.h., it would do 33,000 foot-pounds of work per minute, this being equal to 150 times 220, or 33,000 foot-pounds, or 1 horsepower.

Energy. Energy is defined as the capacity for doing work. When a 1-pound weight has been raised 1 foot, it is said to have 1 foot-pound of work greater potential energy than it had in its original position. The energy

possessed by a body, such as a tractor, due to its motion, is termed *kinetic* energy. *Inertia* is the property of a body which causes it to tend to continue in its present state of rest or motion unless acted upon by some force such as a brake.

Simple Machines. A machine is a device that gives a mechanical advantage which facilitates the doing of work. The term is usually associated with such tools as grain binders, threshing machines, mowing machines, and so forth. But really, such machines are made up of many simple machines. There are six simple machines, namely:

1. The lever
2. The wheel and axle
3. The pulley
4. The inclined plane
5. The screw
6. The wedge

Any simple machine is capable of transmitting work done upon it to some other body. The *mechanical advantage* of a machine is the ratio of the force delivered by the machine to the force applied. The force which operates the machine is called the *applied* force. The *efficiency* of the machine is the ratio of the work accomplished by the machine to the work applied to the machine. If the efficiency of a machine could be 100 per cent, perpetual motion would exist. Since there is always a loss due to friction, the efficiency of the machine falls below 100 per cent.

Lever. The lever is a rigid bar, straight or curved, which rotates about a fixed point called the *fulcrum.* It has an applied force and a resisting force that are well defined by their names. The lever arms for a straight bar are the parts or ends on each side of the fulcrum if the forces act perpendicular to the bar. The mechanical advantage of the lever is the ratio of the length of the lever arm of the applied force to the length of the arm of the resistance force, or

$$\text{Weight} \times \text{weight arm} = \text{applied force} \times \text{force arm}$$

Levers are of three classes (Fig. 3-2). In the lever of the first class, the applied force is at one end and the resisting force, or force exerted by the object to be moved, at the other. The fulcrum, or fixed point, is placed between the applied and the resisting forces. Such a lever may have a mechanical advantage of any value, depending directly upon the length of the lever arm between the fulcrum and the point of applied force as compared with the length of the lever arm between the fulcrum and the point of resisting force. The majority of levers found on farm machinery will fall in this class.

Levers of the second class have the applied force at one end, the fulcrum at the other, and the resisting force between them. This class of levers will have a mechanical advantage that will always be greater than

unity. As in the case of the lever of the first class, a lever of the second class sacrifices speed and distance for a gain in pull or force.

A lever of the third class has the resisting force at one end, the fulcrum at the other, and the applied force between them. The mechanical advantage of this kind of lever is always less than unity, and unlike the two previous classes, work is sacrificed for a gain in speed and distance. An ordinary crane is a lever of this kind.

Wheel and Axle. This is a modification of the lever and acts on the same principle, only the forces operate constantly (Fig. 3-3). The center of the axle corresponds to the fulcrum, the radius of the axle to the short arm, and the radius of the wheel to the long arm. The mechanical advantage is expressed by the equation

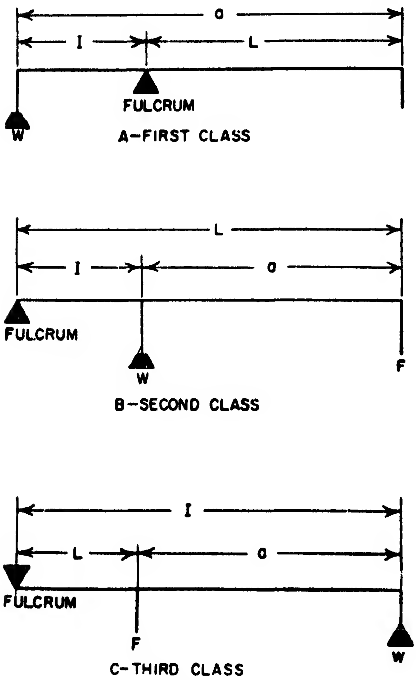

Fig. 3-2. The three classes of levers.

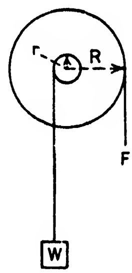

Fig. 3-3. Wheel and axle.

$$F \times R = W \times r$$

where W = weight
F = force applied
R = radius of wheel
r = radius of axle

Pulley. A pulley consists of a grooved wheel turning freely in a frame called a *block;* it is a lever of the first or second class. There are several different applications of pulleys, depending on their arrangement. A single fixed pulley affords no mechanical advantage except to change the direction of motion. When one or more fixed pulleys and one or more movable pulleys (Fig. 3-4) are used in combination, they form the *block and*

tackle. The mechanical advantage varies directly as the number of ropes that support the movable pulley and the weight,

$$w \times h = F \times 3h$$

or $$\frac{w}{F} = 3 \text{ theoretical mechanical advantage}$$

where w = weight
h = distance weight moves
F = force applied
3 = number of ropes supporting w

The *differential pulley* (Fig. 3-5) is a modification of a block and tackle but differs in that the two pulleys D and C are of different radii and

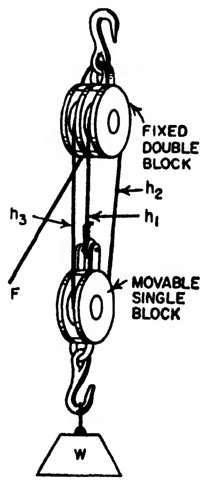

Fig. 3-4. Block and tackle.

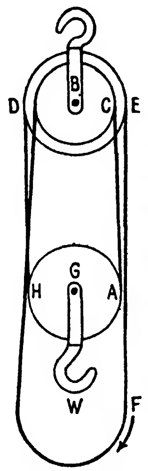

Fig. 3-5. Differential hoist.

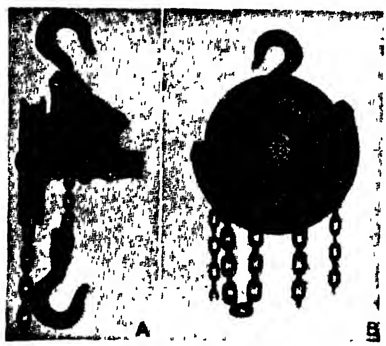

Fig. 3-6. Geared differential hoists: *A*, worm-geared hoist; *B*, planetary-geared hoist.

rotate as one piece about a fixed axis B. The endless chain passes under and supports the movable pulley G and any weight attached to it. To raise a load, force is applied downward to chain F, which will rotate pulleys C, D, and G, causing the chain to wind up on the larger fixed pulley D and unwind on the smaller fixed pulley C, thus raising movable pulley G. In operation consider that point D of the section of chain DH moves up through an arc whose length is equal to BD. At the same time the point C of the section of chain CA will move downward an arc, a distance equal to BC. The length of the chain loop $DHAC$ will be shortened to $BD - BC$, which will cause pulley G to be raised half this

amount. P, the pulley force, is then applied to the section of chain EF, and the weight W is lifted at G. The mechanical advantage will be

$$P \times BD = W \times \tfrac{1}{2}(BD - BC)$$

Figure 3-6 shows a geared differential hoist.

Inclined Plane. The inclined plane, shown in Fig. 3-7, is an even surface sloping at any angle between the horizontal and the vertical. The law or principle which governs the *inclined plane* in mechanics is that the force applied is increased as many times as the length of the inclined plane is greater than the elevation H. Briefly, it is equal to the length over the height, varying with the direction in which the force is applied. Instead of lifting the entire weight of the object vertically, part is supported on the plane and part by the force. Referring to Fig. 3-7, if the force F causes the weight W to move from A to C and parallel to the plane, the work done is F times AC, while the work done against gravity is the weight W times CE if friction is disregarded, or briefly,

$$F \times AC = W \times CE$$

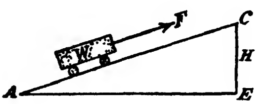

Fig. 3-7. The inclined plane.

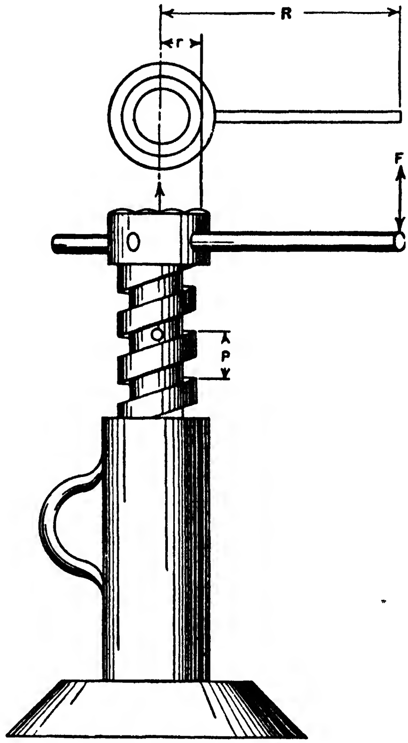

Fig. 3-8. Screw.

If the force is parallel to the base AE, the advantage would be

$$F \times AE = W \times CE$$

Screw. The screw (Fig. 3-8) is the application or modification of the inclined plane combined with the lever. The threads winding around a cylinder bear the same relation to the inclined plane that a winding staircase bears to a straight one. When the screw is turned on its axis with the

aid of a lever or gear, its sloping thread causes the load to move slowly in the direction of its vertical axis. The vertical distance between threads is called the *pitch* of the screw. The mechanical advantage is figured upon the condition that the applied force moves through a distance equal to the circumference of a circle whose radius is the length of the jackscrew bar or the radius of the driving gear, while the weight is being moved through a distance equal to the pitch of the screw.

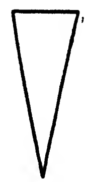

Fig. 3-9. Wedge.

Wedge. The wedge is a modification of the inclined plane. Actually it consists of two inclined planes placed base to base (Fig. 3-9). The force pushing on the wedge into any material, such as a log, will cause forces to act perpendicular to each of the two faces of the wedge.

REFERENCES

Clyde, A. W.: Mechanics of Farm Machinery, *Farm Impl. News*, January–March, 1944.

Fairès, Virgil M., and Robert M. Keown: *Mechanism*, McGraw-Hill Book Company, Inc., New York, 1960.

QUESTIONS AND PROBLEMS

1. In Fig. 3-2*A*, a force of 80 pounds is exerted at W; $l = 12$ inches and $L = 32$ inches. Find the value of force F required to balance the lever.

2. In Fig. 3-2*B*, a weight of 90 pounds is supported at W; l is 10 inches. The total length of L of the lever is 25 inches. Find the value of F.

3. In Fig. 3-2*C*, $F = 28$ pounds; $L = 10$ inches, $a = 24$ inches. What is the weight supported at W?

4. The radius of a roller on which is wound the lifting rope of a windlass is 4 inches. What force must be exerted at the end of a crank arm 24 inches in length attached to the shaft to lift one ton (2,000 pounds)? $W = 2{,}000$; $R = 24$; $r = 4$ (Fig. 3-3).

5. In Fig. 3-4 is shown a block and tackle. The pulleys turn freely on a pin. There are three parts of rope. If 90 pounds is to be lifted, what force is required at the end of the rope F?

TRANSMISSION OF POWER

4

The method of transmitting power from its source to the point of use is one of the greatest problems of the farm-equipment designer. The problem is relatively simple when a tractor is used to operate a threshing machine. The size and speed of the pulleys on the two units are approximately the same. The tractor pulley is lined up with the thresher pulley, and a flat belt is fitted over them and tightened by backing the tractor. The power is ready to be transmitted from the tractor to the thresher. But the problem is multiplied many times in the case of a self-propelled combine, where the source of power is an engine mounted on the machine. Power must be transmitted to a slow-revolving reel and to a high-speed fan. Rotating movement must be changed into back-and-forth movement for the knife on the cutter bar and to an oscillating or shaking movement for the straw rack and grain pan. All this is done by means of pulleys and belts, sprocket wheels and chain, gears, and shafts. The operation is made possible by having good bearings to support the shafts and parts. The various parts of the machine are held together by different kinds of bolts and screws. Therefore, it is well to learn something about all these units to have an appreciation of their use in the design and construction of farm equipment.

METHODS OF TRANSMITTING POWER

The methods of transmitting power in connection with farm equipment are (1) direct drive, (2) pulleys and belts, (3) sprocket wheels and

chain, (4) gears, (5) shafts and universal joints, and (6) flexible shafting.

Direct Drives. When a machine is driven directly from the shaft of an electric motor or internal-combustion engine, this is termed a *direct drive* or *direct connection.* Feed mills and centrifugal water pumps are often driven in this manner. There is usually a clutch between the power source and the machine.

Pulleys and Belts. A belt of flexible material forming a band about two or more pulleys is a simple method of transmitting power in farm equipment. Belts can be used in many intricate patterns over several pulleys

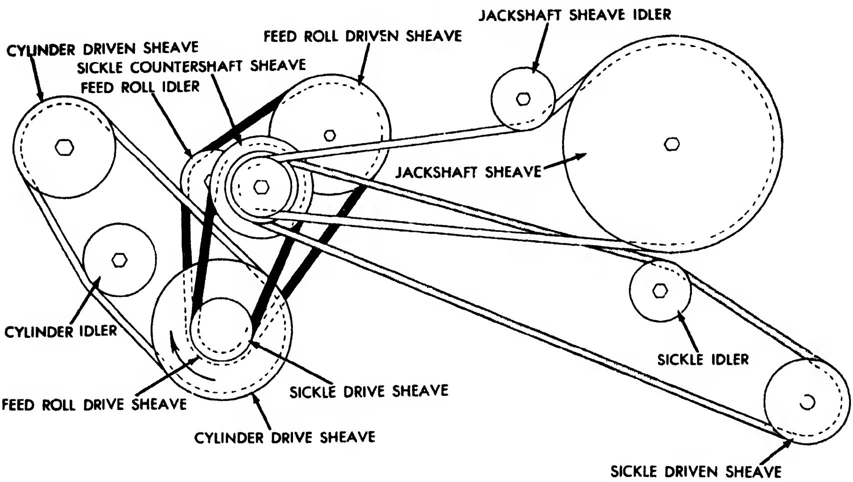

Fig. 4-1. Diagram of V-belt power transmission on a field forage harvester.

on parallel shafts as shown in Fig. 4-1. The pulleys and belts may be either flat or V-shaped.

Flat Belts. The most common belting materials are leather, rubber, and canvas (Fig. 4-2). The principal use of flat belts on field equipment is in elevator chutes to convey harvested crop material from the harvester to a trailer. These belts are made mostly from rubber and canvas belting. Leather belting is expensive, must be kept dry, and is not commonly used on farm equipment. The standard belt speed for farm tractors should be 3,100 feet per minute ± 100 feet per minute.[1] Metal fasteners are generally used to join the two ends of flat belts (Fig. 4-3).

V Belts. The trapezoidal-shaped or V belts are so named because the sides of the belts are beveled to fit into the V slot of a pulley or sheave. The frictional contact between the sides of the belt and the sheave flanges results in less belt slippage and in better power transmission than is ob-

[1] ASAE-SAE Standard, 1944.

tained with flat belts. Figure 4-4 shows the actual cross-sectional sizes and dimensions of the five V-belt sizes. The size of a V belt is referred to by the letter designation of *A*, *B*, *C*, *D*, and *E*, with *A* being the smallest and *E* the largest. Double-sided V belts are almost hexagonal in shape. This type is designed to drive from either or both sides.

Fig. 4-2. Different kinds of flat belting: *a*, leather; *b*, stitched canvas; *c*, balata; *d*, rubber; *e*, solid woven.

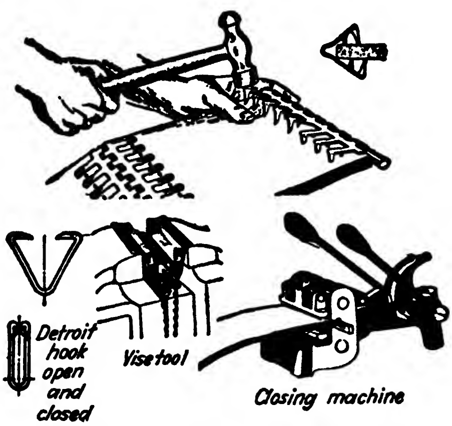

Fig. 4-3. Methods of closing metal belt laces: Alligator *above*, Clipper *below*.

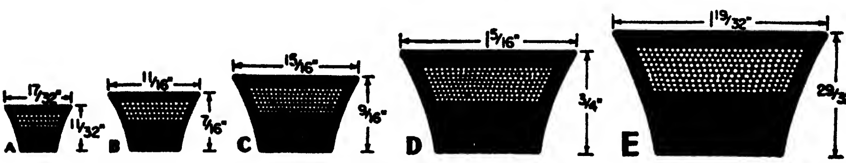

Fig. 4-4. The actual cross-sectional sizes of five sizes of V belts.

The designer who wishes to use V belts on a piece of farm equipment calculates the power requirements for the various units and selects the V-belt size needed to transmit the necessary power. If large amounts of power are required, two or more belts can be used with multiple-groove sheaves (Fig. 4-5). V belts can be used to transmit power between sheaves for distances ranging from a few inches to several feet in many different arrangements (Figs. 4-1 and 4-6).

A V belt should ride with the top surface almost flush with the top of the sheave groove. There should be at least ⅛-inch clearance under the belt in the bottom of the sheave groove.

Generally, V belts are made in endless lengths and used where the belts can be permanently installed or put on the sheaves without dismantling parts of the machine. However, special V-belt fasteners (Fig.

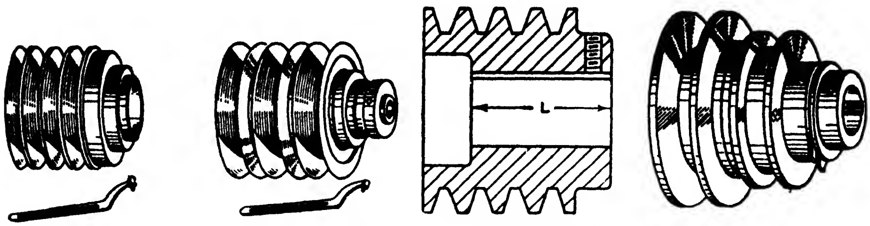

Fig. 4-5. Adjustable and nonadjustable multiple-groove sheaves for V belts.

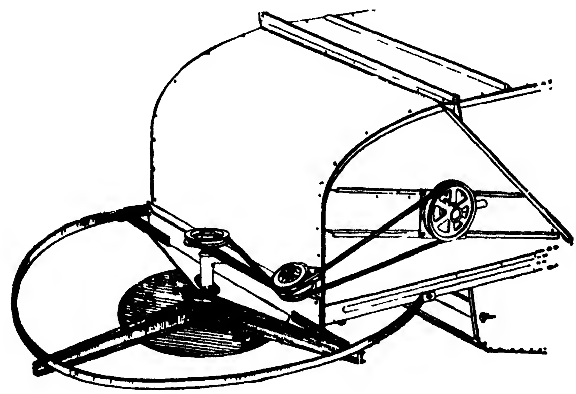

Fig. 4-6. V belts can be used to transmit power around corners.

4-7) make it possible to use open-end V-belt applications over drives that would be costly to dismantle.

How to Measure the Length of a V Belt. When the drive consists of two sheaves (Fig. 4-8), the relation between the center distance between shafts and the belt length can be determined by the following formula:

$$L = 2C + 1.57(D + d) + \frac{(D - d)^2}{4C}$$

where L = effective length of belt, inches
C = distance between centers of sheaves, inches
D = effective outside diameter of large sheave, inches
d = effective outside diameter of small sheave, inches

Pulleys and Sheaves. Pulleys for flat belts are manufactured from wood, cast iron, steel, and composition fiber. The diameter of a flat pulley is slightly larger at the center than at the edges. This is called the *crown* of the pulley.

Sheaves for V belts are made from cast iron, cast semisteel, and die-pressed steel. Many single- and multiple-groove sheaves are adjustable to permit the belt to ride higher or lower in the groove and give a variable speed ratio between sheaves (Figs. 4-9 and 4-10). The belt should not be run lower in the adjustable sheave than its approximate thickness or lower than the angled sides of the groove.

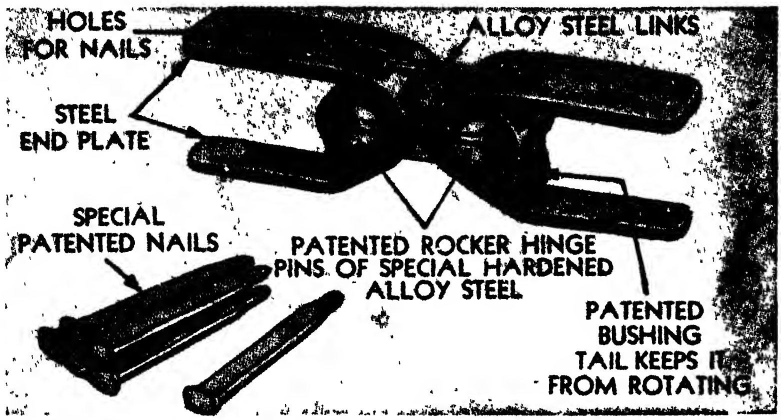

Fig. 4-7. Connections for open-end V belts.

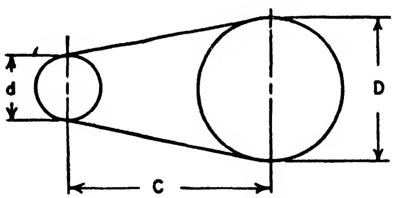

Fig. 4-8. The relation between center distance and V-belt length.

Some Useful Rules for Belts. To find the length of a flat belt for two pulleys of unequal size, add the diameters of the two pulleys together, divide this sum by 2, multiply by 3, and to this product add twice the distance between the centers of the two shafts.

To calculate the speed or size of a pulley: the revolutions per minute of the driving pulley times its diameter equals the revolutions per minute of the driven pulley times its diameter. If three of the quantities are known, the fourth can be easily determined.

$$S \times D = S \times D$$

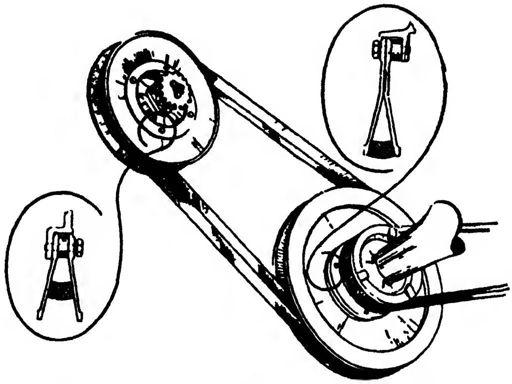

Fig 4-9. Variable speeds are obtained by changing the sheave pitch. The pitch of alternate sheaves can be changed.

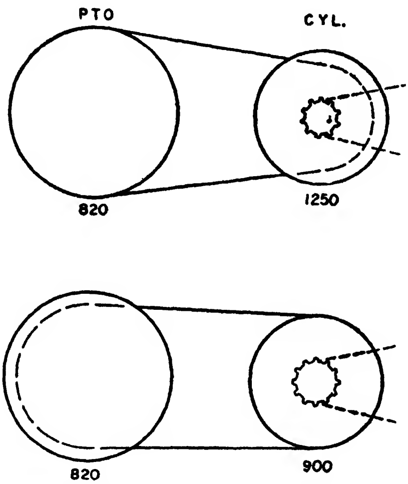

Fig. 4-10. Variable speeds are obtained by changing the sheave pitch of alternate sheaves.

where S = r.p.m.
D = diameter

Another expression is

$$\text{Diameter of driving pulley} = \frac{\text{r.p.m. of driven} \times \text{diam. of driven}}{\text{r.p.m. of driver}}$$

The speed or revolutions per minute can be determined by substituting the known and unknown quantities as

$$\text{R.p.m. of the driving pulley} = \frac{\text{diam. of driven} \times \text{r.p.m. of driven}}{\text{diam. of driving pulley}}$$

To find the speed of a belt, multiply the circumference of the pulley by the number of revolutions at any given time. This disregards slippage and creep. The speed of a flat belt should not exceed 5,000 feet per minute. A good speed is 3,500 to 4,000 feet per minute.

General Precautions Pertaining to the Use of Belts:

1. Belts that are too tight cause injurious strains on the belts and machinery, resulting in hotboxes and broken pulleys.
2. Belts that are too loose have a flappy, unsteady motion.
3. All belts should be kept free from dirt and moisture.
4. Mineral oils should not be used on leather and rubber belts.
5. Boiled linseed oil or resin mixed with tallow and oil makes a good belt dressing.
6. Belts should be run horizontally or as nearly so as possible.
7. The lower side of a belt should be the driving side, as this gives a greater arc of contact.
8. Idler pulleys should be placed on the slack side of the belt and nearer to the driven pulley.
9. The arc of contact should be 180 degrees and over if possible.
10. A pulley that is too narrow should never be used.

Sprocket Wheels and Chains. Hook-link and roller are the two types of chain commonly used in transmitting power on farm equipment. Sprocket wheels are designed to fit each type of chain.

The *hook-link* chain may be made of either malleable iron or crimped steel (Figs. 4-11 and 4-12). Hook-link chains are used where the power

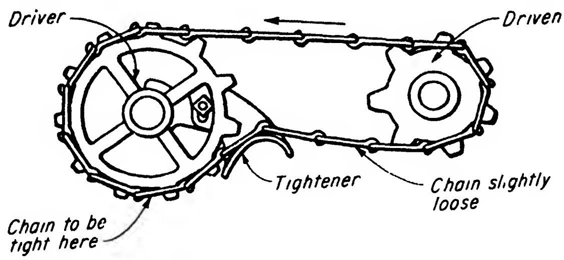

Fig. 4-11. The proper method of running a hook chain on the sprockets.

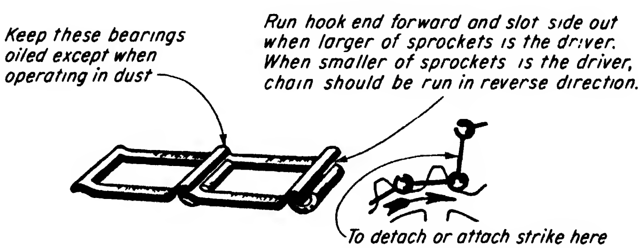

Fig. 4-12. Pressed-steel hook chain.

requirements are low and the speed relatively slow. The steel hook-link chain is most extensively used. In the operation of hook-link chains, the hook of the chain link should be run with the open lip away from the sprocket wheel and leading in the direction of travel, as shown in Figs.

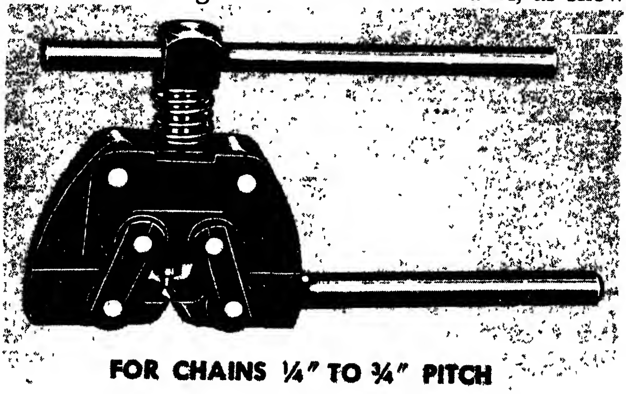

Fig. 4-13. Clamp for disconnecting pressed-steel hook-chain links. (*Acme Chain Corp.*)

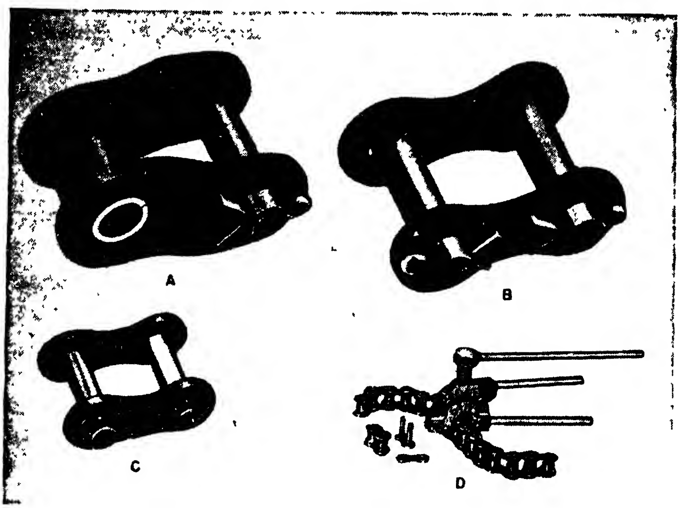

Fig. 4-14. Types of roller-chain links: *A*, offset link; *B*, cottered connecting link; *C*, slip-spring connecting link; *D*, roller-chain pin extractor. (*Link-Belt Company.*)

4-11 and 4-12. There may be exceptions to this rule when the drive pulley is small. Figure 4-13 shows a special clamp for disconnecting pressed-steel hook-chain links.

Roller chains are made of a special high-grade steel and can be used at high speeds. The various parts of the chain, as shown in Fig. 4-14, are

finished, polished, and hardened. Standard sizes of roller chain are designated by the pitch and number. The *pitch* of a chain is the length of each link from center to center of the pins. Pitches of 3/8, 1/2, 5/8, 3/4, and 1 carry corresponding numbers of 35, 40, 50, 60, and 80. Larger sizes are available. Single-width roller chains are more commonly used on farm

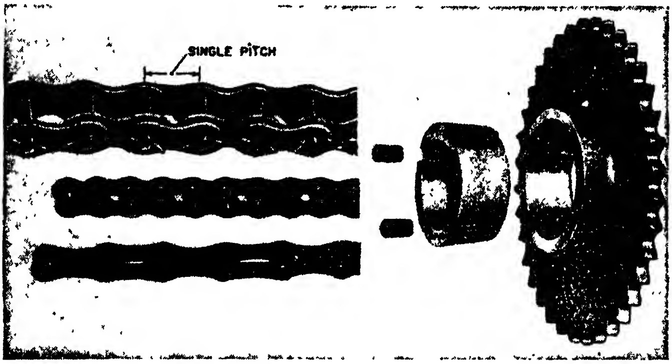

Fig. 4-15. Three types of roller chain and sprocket with taper-lock hub: *top,* cotter pin; *middle,* riveted; *bottom,* double-pitch. (*Link-Belt Company.*)

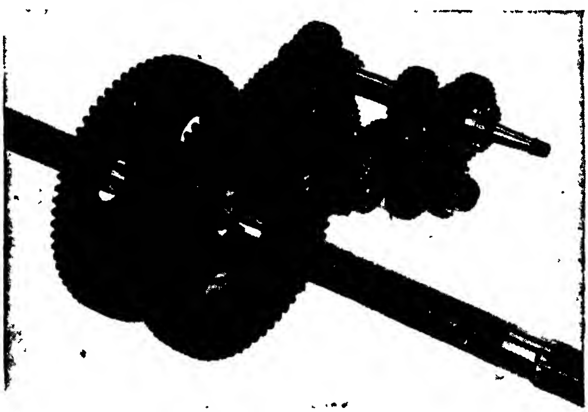

Fig. 4-16. Where transmission shafts are close together, gears are used to transmit power from one shaft to another.

equipment, but double-, triple-, and quadruple-width types are made. For the average application on farm equipment, the single-width roller chains give satisfactory service and are usually more economical. Generally, it is best to use the smallest pitch chain that will accommodate the horsepower and load requirement. Where light loads are transmitted at relatively low speeds, a double-pitch chain can be used (Fig. 4-15). If

possible, operate the chain with the tight span on top. For special applications of roller chain, consult the manufacturer.

Gears. When the machine is rather compact and the shafts are close together, gears can be employed to transmit the power, as shown in Fig. 4-16. The various types of gears are shown in Fig. 4-17.

Often there is a combination of either spur or bevel and other type. If the power is transmitted parallel to the shaft, helical or spur gears are employed, but if the shafts are at right angles, the beveled or worm

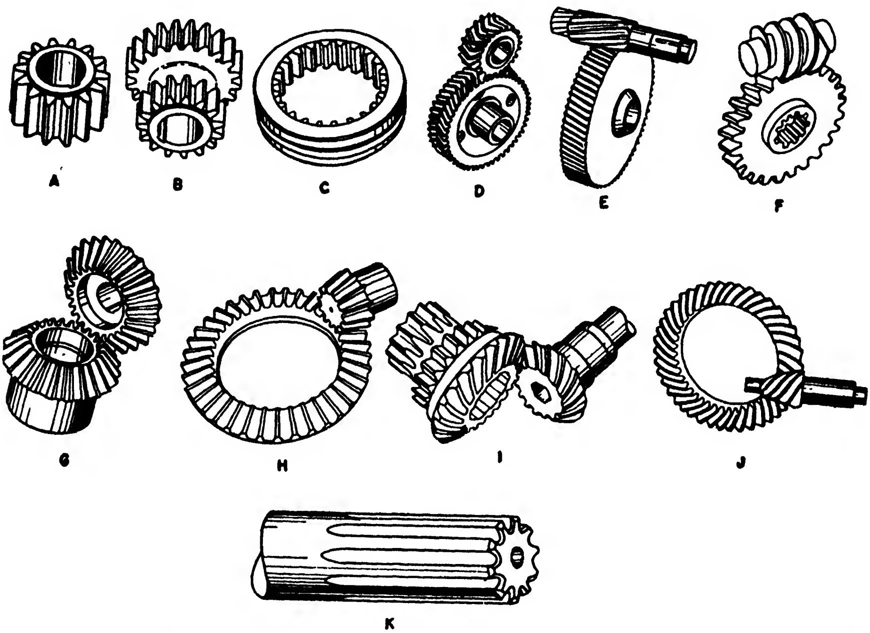

Fig. 4-17. Types of gears: *A*, spur; *B*, cluster; *C*, internal spur; *D*, herringbone; *E*, helical; *F*, worm and worm-wheel; *G*, straight-bevel; *H*, straight-bevel gear set; *I*, spiral-bevel set used in tractors; *J*, hypoid gear set; *K*, spline-shaft gear.

gears must be employed. The use of gears makes a more substantial construction and eliminates a great amount of lost motion; however, the cost is greater, especially in the case of repairs. It is much cheaper to replace one or two links in a chain than to replace a complete gear. When one tooth is broken and all the others remain, the gear cannot be used.

Spur gears have their shafts parallel. The teeth that make up the gear have their surfaces parallel to the shaft. In an *internal* spur gear (Fig. 4-17*C*), the teeth are on the inside of the rim. An *external* spur gear (Fig. 4-17*A*) has teeth on the outside of the rim. For every internal spur gear, it is necessary to have an external spur gear to operate it, but two external gears can be used together without an internal spur gear.

Beveled gears (Fig. 4-17H) have their shafts at right angles or nearly so. Where the power has to turn a corner, beveled gears are used. The teeth are on an incline which varies according to the difference in diameter of the gears meshing together. Beveled gears tend to wear so that their teeth do not fit one another closely. For this reason there should always be some method of adjustment. *Miter* gears have an equal number of teeth cut at the same angle (Fig. 4-17G).

Worm gears (Fig. 4-17F) consist of a shaft, called the *worm*, with screw-like threads which run spirally around it. This meshes with a helical spur gear called the *sector*. As the worm turns, the teeth of the sector, which fit in the grooves, are turned slowly. This type of gear is used to a limited extent in farm machinery.

Helical gears (Fig. 4-17E) may take the form of either spur gears or beveled gears, but they do not have straight teeth. The teeth are more or less curved so that they will remain in mesh or in contact longer than straight teeth. In the spur gear, they are called *helical spur gear;* in the beveled type they are called *helical beveled gear*. When helical gears are used, much noise is eliminated because of the fact that the teeth remain in contact longer, giving an even, constant pressure at all times.

A *pinion* is the smaller gear of any two gears that are meshing together; it may be a spur, bevel, or helical gear.

Power Take-off Shafts and Universal Joints. In the operation of many farm machines, the tractor is used to move the machine forward and at the same time furnish the power for its operation. The power is transmitted from tractor to machine by means of a shaft which is usually termed a *power take-off shaft*. If the travel of the tractor and the machine were always in a straight line, a solid shaft could, in many cases, be used. Field operation requires turning of corners in harvesting broadcast crops and back-and-forth trips for row crops. Thus, the power take-off shaft must be equipped with at least two universal joints to permit these turns (Figs. 4-18 and 4-19). The complete shaft including universal joints is called a *power take-off drive*. Shafts and universal joints are frequently employed, also, to transmit power at various angles on a particular machine.

In 1946, the American Society of Agricultural Engineers and the Society of Automotive Engineers approved standards establishing the dimensional relationships necessary to permit any tractor to be hitched successfully to any implement.[2] These standards require that the location of the power take-off shaft shall be within the limits of 3 inches to the right or left of the center line of the tractor. The standard speeds of power take-off drives are 540 and 1,000 r.p.m. A shield is required for the power take-off shaft of the tractor and must be strong enough to support

[2] Power Take-off for Farm Tractors, *Agr. Engin. Yearbook*, 1962.

the weight of the operator. The manufacturer of the driven machine must furnish shielding for the shafting.

The maximum instantaneous-torque starting values are more important considerations in designing a power take-off drive than the average horsepower requirements of the operation. This is illustrated in Fig. 4-20. The data in Table 4-1 show the power take-off torsional loads for several implements performing different farm operations.

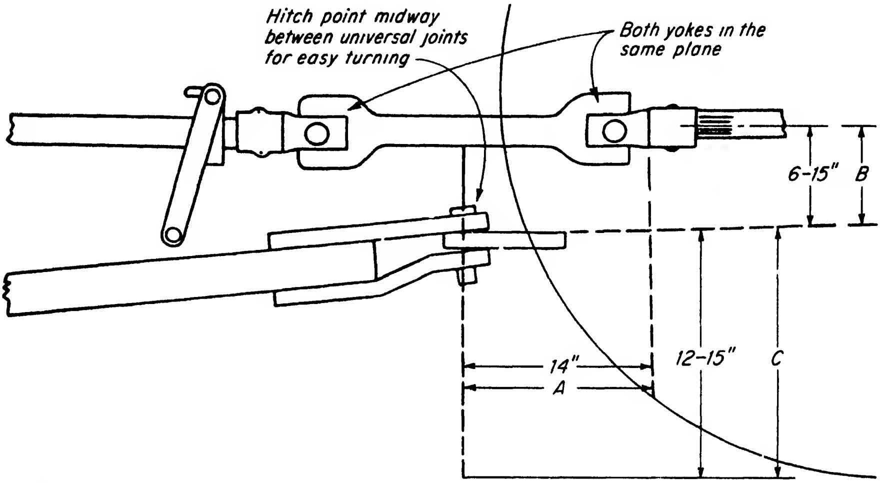

Fig. 4-18. Proper application of hitch and universal joints. Power-take-off-driven machines have been standardized so that all makes of tractors and machines can be connected with greater safety.

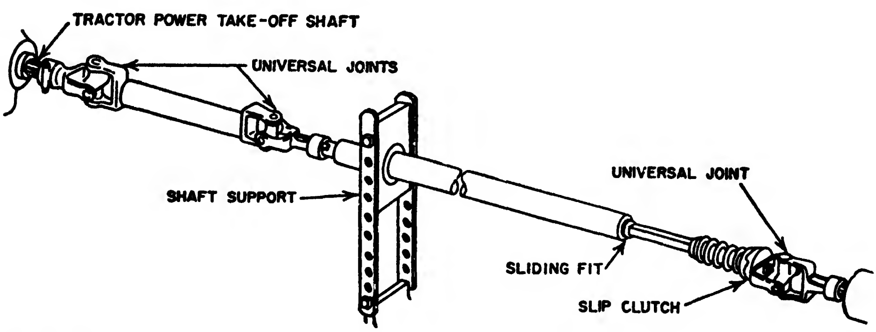

Fig. 4-19. Complete power take-off shaft with three universal joints, safety snap clutch, and shaft support. The safety shield has been removed to show all parts of the assembly.

Where flexibility is desired in transmitting light loads a distance of a few inches, a piece of thick-walled rubber hose may serve as a universal joint.

TABLE 4-1. POWER TAKE-OFF TORSIONAL LOADS

Test no.	Tractor model	Approx. max. tractor, b.hp.	Implement make and model	Coupling in P.T.O. drive	Max. starting torque, lb.-in.		Max. operational torque peaks, lb.-in.		Avg. torque under normal operating conditions, lb.-in.	Work being performed
					With normal clutch engagement	With rapid clutch engagement	Average conditions	Near plugged conditions		
1	1	35	Ensilage harvester *A*	Standard	4,900–6,400	10,800–15,370	4,680–6,390	5,450–7,140	2,720	Chopping heavy drilled corn
2	1	35	Ensilage harvester *A*	Spec. slip	....	8,660*	5,112–5,723	6,025–6,865	3,200	Chopping heavy drilled corn
3	9	40	Ensilage harvester *A*	Standard	....	11,600	4,700–4,925	6,200–8,025	3,261	Chopping heavy drilled corn
4	1	35	Ensilage harvester *B*	Standard	2,600–4,000*	. ...	3,520–3,820	3,960–7,630*	2,390	Chopping heavy drilled corn
5	1	35	Forage harvester *C*	Standard	.. ..	14,600	3,730–7,200	6,370–7,200	2,870	Chopping green alfalfa
6	1	35	Forage harvester *C*	Spec. slip	. ...	9,800–7,530*	5,230–6,700	6,100–8,700	3,270	Chopping green alfalfa
7	1	35	Forage harvester *C*	Standard	....	12,500–10,900	6,060–7,460	9,500	3,600	Chopping green alfalfa
8	1	35	Forage harvester *C*	Standard	.. . ..	21,400	.. . .	....	.....	Attempting to start plugged machine
9	1	35	Corn picker *D*	Standard	1,570–1,740	3,990	822–1,031	. ...	727	Picking corn
10	1	35	Baler *E*	Standard	... .	18,300–20,600	5,860–7,470	12,100	1,140	Baling alfalfa
11	1	35	Baler *E*	Standard	13,100	....	6,550–8,140	11,600–15,000	1,545	Recheck of test 10
12	1	35	Baler *E*	Spec. slip	10,700–12,100*	10,700–12,100*	7,250–8,920	11,500–13,300*	2,250	Baling alfalfa

TABLE 4-1. POWER TAKE-OFF TORSIONAL LOADS (Continued)

Test no.	Tractor model	Approx. max. tractor, b.hp.	Implement make and model	Coupling in P.T.O. drive	Max. starting torque, lb.-in.		Max. operational torque peaks, lb.-in.		Avg. torque under normal operating conditions, lb.-in.	Work being performed
					With normal clutch engagement	With rapid clutch engagement	Average conditions	Near plugged conditions		
13	1	35	Baler *E*	Spec. slip	10,100*	.....	8,600–11,100	10,350–12,600	1,580	Baling straw
14	9	40	Baler *E*	Standard	12,250	.....	7,749–10,945	10,960–12,095	1,938	Baling alfalfa
15	1	35	Baler *E*	Standard and universal joints aligned	Standard and universal joints aligned	Standard and universal joints aligned	4,601–5,867	.....	1,383	Baling alfalfa
16	1	35	Baler *F*	Standard	16,500	.....	8,600	22,700	.....	Baling alfalfa
17	1	35	Baler *F*	Spec. slip	5,000*	5,000*	5,000*	5,000*	.....	Baling alfalfa
18	1	35	Combine *G*	Standard	.....	10,100–16,600*	3,760	9,380	1,890	Combining windrows
19	1	35	Combine *G*	Spec. slip	.....	.....	7,150	7,760–9,130	1,700	Combining windrows
20	1	35	Combine *G*	Spec. slip	.....	7,350–8,650*	4,160–4,200	7,470	1,600	Straight combining
21	2	25	Hammer mill *H*	Standard	9,030	17,500–20,150	4,145	7,270	2,700	Grinding ear corn
22	1	35	Hammer mill *H*	Standard	6,130	.....	3,740	14,900	2,140	Grinding ear corn
23	1	35	Hammer mill *H*	Spec. slip	8,230*	8,230*	.....	6,920	4,210	Grinding ear corn
24	4	45	Hammer mill *J*	Standard	18,150	25,800	7,800	13,000	5,450	Grinding ear corn

* Safety clutch in P.T.O. line slipped, limiting torsional load to this value.

SOURCE: *Agr. Engin.*, **33**:68, 1953.

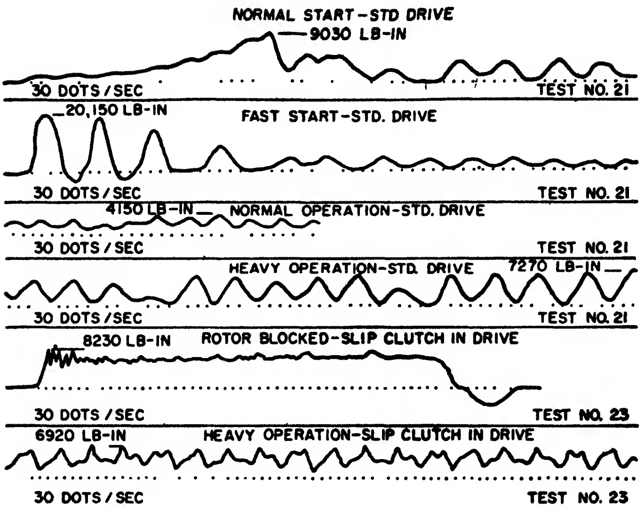

Fig. 4-20. Torque-meter chart showing the effect of a frictional slip coupling designed to operate at relatively high torsional loads. [*M. Hansen, Agr. Engin.*, 33(2): 69, 1952.]

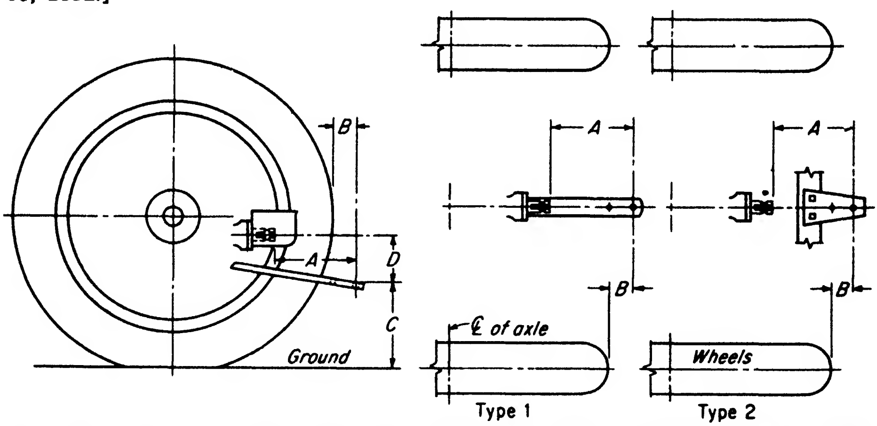

Fig. 4-21. Drawbar hitch and power take-off for farm tractors having a 1,000-r.p.m. power take-off.

To simplify the transmission of power to machines requiring high speeds many tractors are equipped with a 1,000-r.p.m. power take-off. The American Society of Agricultural Engineers has set up standards for its operation.[3]

1. The diameter of the hitch hole (Fig. 4-21) at the end of the tractor drawbar shall be not less than $1\frac{3}{16}$ inch, and in addition, an $\frac{11}{16}$-inch hole shall be provided in the drawbar 4 inches ahead of the hitch hole.

[3] *Amer. Soc. Agr. Engin. Yearbook,* p. 54, 1962.

2. The material in the tractor drawbar shall clear an implement clevis (3 inches wide and having a 3-inch throat clearance) through a 90-degree swing right or left of the tractor drawbar center line.
3. The horizontal distance (*B*, Fig. 4-21) between the hitch point on the tractor drawbar and the rearmost point on the standard-sized rubber tire, steel wheel rim lug, or tractor fender shall not be less than 3 inches.
4. The position of the tractor drawbar for power take-off work shall be such that the vertical distance (*C*, Fig. 4-21) from the ground line to the top of the drawbar at the hitch point shall be 15 inches ± 2 inches when the tractor is equipped with regular-sized tires.

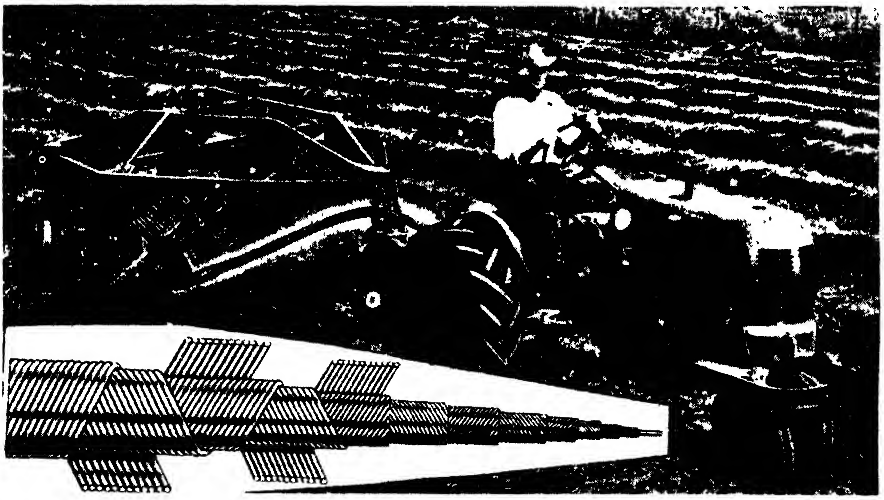

Fig. 4-22. Flexible shaft operating side-delivery hay rake. The inset shows the construction of one type of flexible shafting. (*Stow Mfg. Company.*)

5. The horizontal distance (*A*, Fig. 4-21) between the hitch point on the tractor drawbar and the end of the splined shaft of the power take-off shall be 16 inches. The hitch point shall be directly in line with the center line of the power take-off shaft, and provision shall be made on the tractor for locking the drawbar in this position.
6. The vertical distance (*D*, Fig. 4-21) between the top of the drawbar at the hitch point and the center line of the power take-off splined shaft shall not be less than 6 inches or more than 12 inches, 8 inches being the recommended dimension.
7. The location of the tractor power take-off shaft shall be within the limits of 1 inch to the right or left of the center line of the tractor, the tractor center line being the recommended location.

Flexible Shafting. A strong and durable flexible shaft can be used in many cases for the transmission of power in farm power equipment, replacing exposed universal joints and shafts. Figure 4-22 shows an application of

flexible shafting for transmitting power from a tractor to the reel of a side-delivery hay rake.

TYPES OF CLUTCHES

A *clutch* is a gripping device between a power source and a machine or between working the parts in a machine whereby the units can be connected or disconnected. In the operation of farm power equipment, clutches permit the starting of the engine with the machine disconnected. The clutch is then engaged, and the power transmitted to the machine by means of shafts, gears, belts, and other devices.

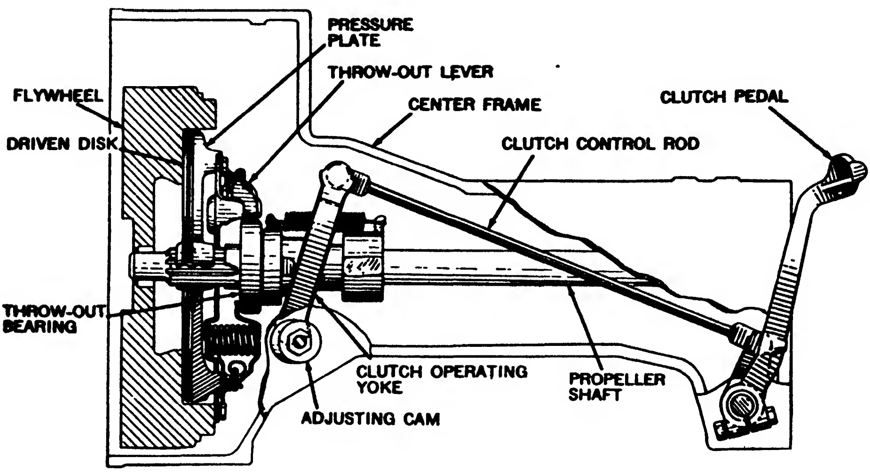

Fig. 4-23. Friction clutch.

Clutches are either *friction* or *positive* types. Friction clutches are used in tractors, trucks, and other equipment such as self-propelled combines and cotton harvesters in which power must be applied gradually to the load (Fig. 4-23). This type of clutch usually has flat plates covered with friction material which are held against each other by springs so that they turn as a unit, thus transmitting power.

Slip or *safety snap clutches* are a type of friction clutch. The two notched plates are pressed together by springs of sufficient force to transmit power for normal working loads. Should an overload occur, the clutch will slip with a snapping action and prevent damage to the working unit (Fig. 4-24). This type of safety clutch is used on many power-operated machines, such as corn pickers, forage harvesters, and haying machinery.

Positive clutches consist of two parts which have jaws so shaped and placed that, when they are brought together, they engage positively as a

unit with no slippage (Fig. 4-25). These clutches should be engaged before power is applied to the driving side. They are used when light loads are transmitted at slow speeds, as in drives for planters and grain drills.

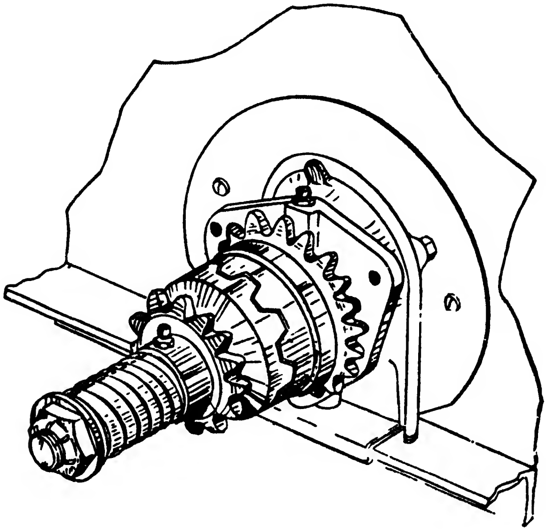

Fig. 4-24. Safety snap clutch.

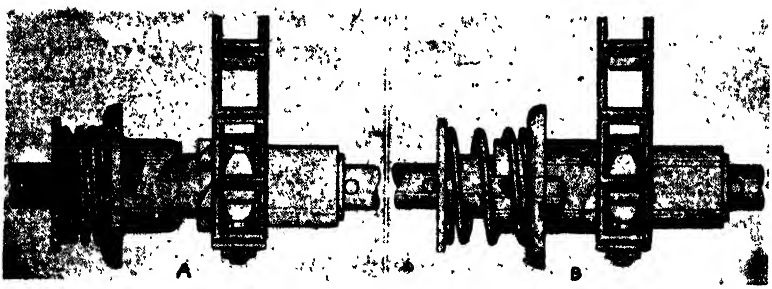

Fig. 4-25. Positive-type clutch: *A*, clutch parts disengaged; *B*, clutch parts engaged to transmit power.

The *ratchet-and-pawl* arrangement, as found in the hubs of horse-drawn mowing machines and in the drives of manure-spreader aprons (Fig. 4-26), is a type of clutch. The ratchet is composed of gearlike teeth. These teeth generally have an equal slope from the vertex of the teeth on each side, or they may take a form similar to circular-saw teeth. The pawls, or *dogs*, consist of small pieces of cast iron that fit into recesses in a casting rigidly fastened to the axle. The outer ends of the pawls are

held against the ratchet teeth by small coil expansion springs. As the machine moves forward, the three or four pawls engage the ratchet teeth and the axle turns with the wheel. A movement backward allows the pawls to slip over the teeth with a distinct clicking noise. Therefore, this type of clutch operates in only one direction.

The *overriding clutch* is a type of ratchet-and-pawl arrangement (Fig. 4-27). In some types, balls placed in tapered recesses take the place of

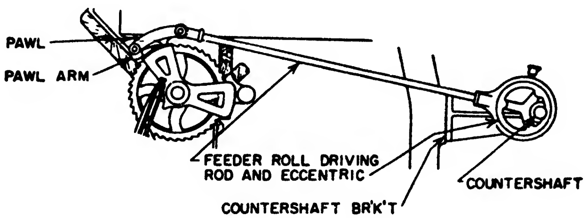

Fig. 4-26. Ratchet-and-pawl drive for manure-spreader apron. Note the eccentric drive for moving the pawl forward and backward.

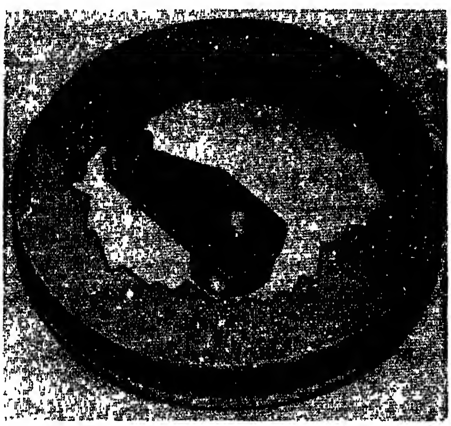

Fig. 4-27. Overriding- or overrunning-type clutch.

the rectangular metal pawl. The overriding-type clutch is often used to operate fans on cotton-picking machines and forage harvesters. When the power is disengaged, the fan keeps turning to clear out any material that may be in the pipes until it finally comes to a stop from the lack of power.

Another type is the *belt-tension clutch.* When an idler on a belt is mounted so it can be moved to release the tension around the pulleys, there is not enough friction on either the drive pulley or the driven pulley to transmit power. Thus, the tension applied by the movement of the idler pulley can be made to serve as a clutch to engage and disengage the power.

Electric and hydraulic clutches are used on some machines, such as combines.

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QUESTIONS AND PROBLEMS

1. Enumerate the various methods of transmitting power in farm equipment. (*a*) Explain the merits of each method. (*b*) Explain the difference between a direct and a flexible shaft drive.

2. (*a*) Explain how the sizes of V belts are designated. (*b*) How is the pitch length designated? (*c*) Explain what is meant by a double-sided V belt.

3. The centers of two B-type V-belt sheaves are 24 inches apart. The drive sheave has a pitch diameter of 14 inches, while the driven sheave has a pitch diameter of 5 inches. Find the length of V belt required. Take into consideration the installation take-up allowance.

4. Explain the differences between and the uses of (*a*) single sheave, (*b*) multiple sheave, (*c*) variable-speed sheave.

5. Under what conditions are the following used: (*a*) hook-link chain, (*b*) roller chain?

6. Enumerate the various types of gears and explain their special uses.

7. A tractor is used to operate the horizontal-rotating knives of a stalk cutter-shredder. The tractor power take-off runs at 540 r.p.m. and drives a pinion gear with thirteen teeth. The driven gear has twenty-four teeth. (*a*) Find the revolutions per minute of the knife blades. (*b*) Find the peripheral travel of the blade ends when cutting a circular pattern 57 inches in diameter.

8. Explain the functions of the universal joints in a power take-off drive. What is the accepted standard size of a power take-off shaft for tractors?

9. Explain the differences between the various types of clutches.

10. What are the advantages of an overriding clutch?

COMPONENT PARTS OF MACHINES

5

The component parts of farm equipment include those parts that are essential to construct a complete high-quality operative machine.

Cam. A *cam* (Fig. 5-1) is a device that produces intermittent motion. When an object is in motion part of the time and at rest between mo-

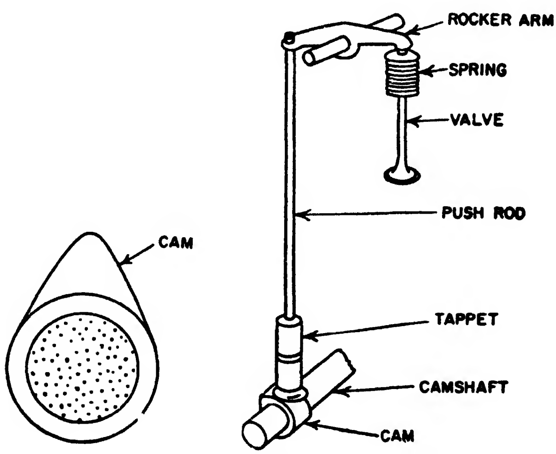


Fig. 5-1. A cam shape at left and the application of a cam at right.

tions, the action is said to be *intermittent*. A cam can best be described as a wheel with a hump on one side (Fig. 5-1). The part that projects is called the *nose*. Anything resting against the cam will be moved only when the nose comes around to it; otherwise, it remains stationary.

Bearings. Bearings in farm equipment are required to hold the various power-transmission parts in position. The proper bearing to use is determined by the amount of wear, the speed at which the shaft is turning, the load it must carry, and the amount of end thrust. Bearings are divided into two general classes: friction, or plain, and antifriction.

Friction Bearings. Bearings of this type are shown in Figs. 5-2 and 5-3. In plain bearings, the revolving shaft is supported by, and is in direct contact with, a fixed bearing surface. For this reason, friction is high, and the bearing should be lubricated with a fairly light oil. The bearing metal may be cast iron, babbitt, bronze, or other material.

Antifriction Bearings. Bearings of this type have balls or rollers placed between the shaft and the supporting bearing, thus reducing the friction. They are, therefore, called *antifriction bearings.* The lubrication of ball

Fig. 5-2. Solid bearing.

Fig. 5-3. Plain or split bearing.

and roller bearings serves to preserve the polished surfaces from corrosion, to act as a cooling agent, and to protect the rubbing surfaces between the rollers, races, and separators. The selection of a lubricant for antifriction bearings is based on the type of bearing housing, the operating temperature, the speed of bearing rotation, and the requirements of the bearing. Some antifriction bearings are packed and sealed, thus requiring no further lubrication for the life service of the bearing. Do not use a detergent oil for lubricating antifriction bearings on electric motors. If used, the bearing is likely to fail in 2 or 3 months. Both ball and roller types of antifriction bearings are used extensively on almost all power-operated farm equipment.

Ball bearings are bearings having one or more rows of small balls placed in a cage or holder (Fig. 5-4). The balls are separated slightly and held in position by a retainer. Because of the small amount of surface in contact between the balls and the shaft, friction is reduced to a very low point. Ball bearings are designed to carry (1) radial loads at right angles to the shaft, (2) thrust forces that are parallel to the shaft or tend to shift the shaft out of position, and (3) a combination of radial and thrust

loads. There are several types of ball bearings (Fig. 5-4). They are designed to carry the various types of loads listed above. Ball bearings have many applications in all types of farm equipment. Pillow blocks for ball bearings are shown in Fig. 5-5.

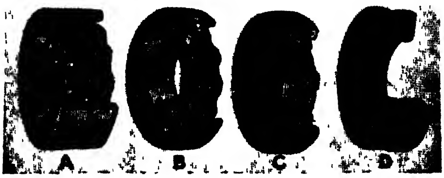


Fig. 5-4. Types of ball bearings: *A*, double-row, *B*, single-row; *C*, single-row with ring seal; *D*, end-thrust.

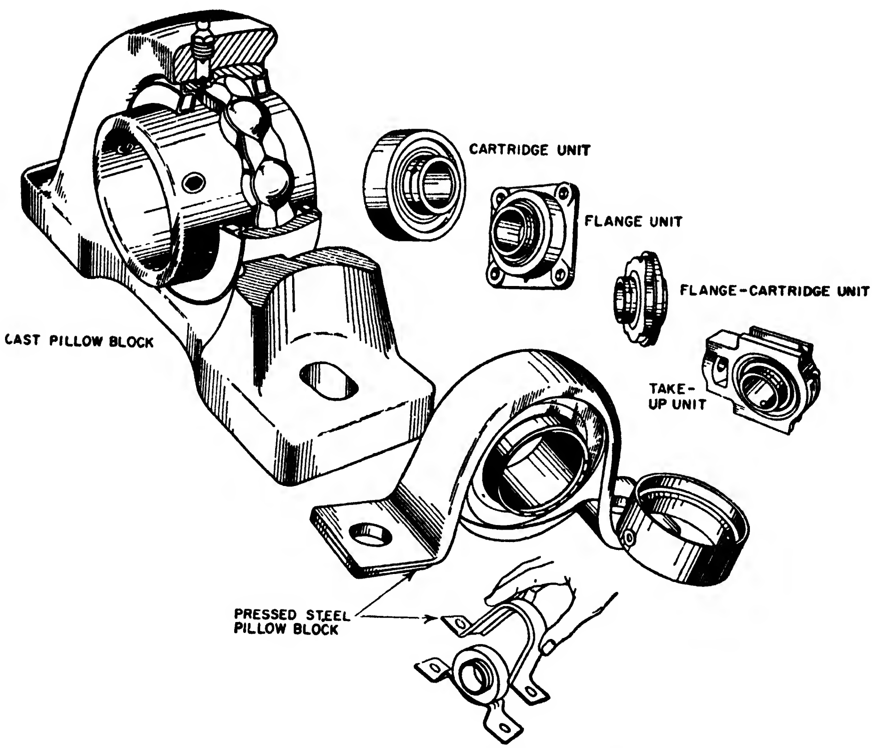


Fig. 5-5. Types of pillow blocks for ball bearings.

Roller bearings differ from ball bearings in that small cylindrical rollers are substituted for the balls. This gives a much larger bearing surface, such as is necessary for a heavy load. There are also cages to hold the rollers apart as in the ball bearings. Figures 5-6 to 5-9 illustrate several

types of roller bearings. Roller bearings may be straight or tapered, depending on the shape and placement of the rollers.

Straight roller bearings can be further divided into (1) the plain roller (Fig. 5-6), (2) the spiral roller (Fig. 5-7), and (3) the needle roller (Fig. 5-8). The plain, straight roller bearing consists of a number of solid-cylinder steel rollers assembled in a cage with an inner and outer

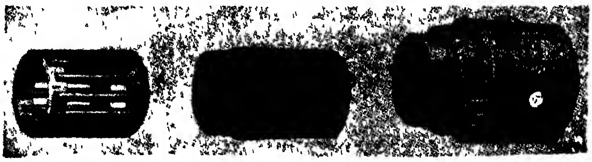


Fig. 5-6. Parts of a plain roller bearing.

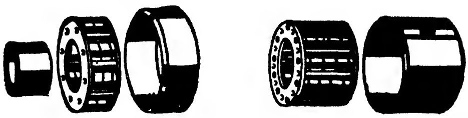


Fig. 5-7. The various parts of two applications of a spiral roller bearing. (*Hyatt Roller Bearing Co.*)

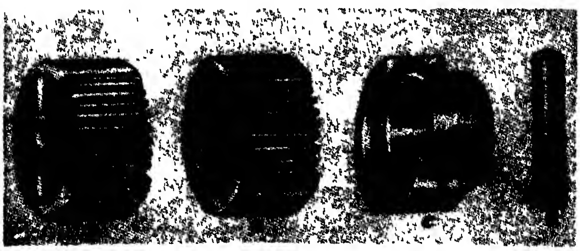


Fig. 5-8. The various parts of a needle roller bearing. (*Torrington Roller Bearing Company.*)

race (Fig. 5-6). One further classification of plain roller bearings is determined by the manner in which the parts are assembled, as a bearing with a separable inner race, a bearing with a separable outer race, and a bearing with nonseparable parts.

The spiral, or wound, straight, hollow roller bearing is shown in Fig. 5-7. Types are designed to operate with inner and outer races or with no inner race and a split outer race.

The needle-type roller bearing consists of a hardened outer shell containing a number of hardened rollers with pointed ends (Fig. 5-8). The

needle bearing has the greatest radial load capacity possible for a given housing bore. It can also be used where the bearing space is limited.

Tapered roller bearings are designed to carry radial or thrust loads or a combination of both. The conical rollers are set in the cage at an angle between the inner and outer races as shown in Fig. 5-9. It is usually necessary to mount tapered roller bearings in pairs in order to balance the radial and thrust loads (Fig. 5-10). Their greatest application is for wheel bearings, but there are many other applications.

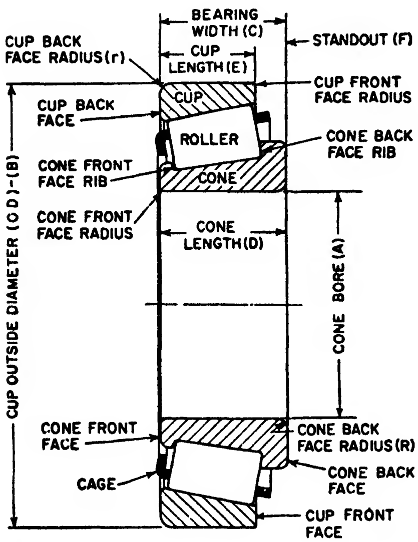


Fig. 5-9. The various parts of a tapered roller bearing. (*Timken Roller Bearing Company.*)

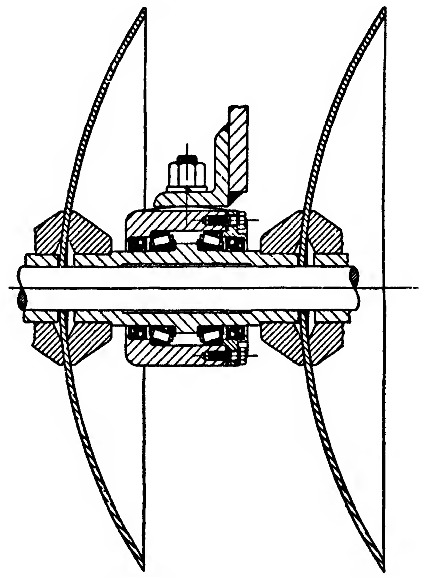


Fig. 5-10. Application of tapered roller bearings on a disk harrow. (*Timken Roller Bearing Company.*)

Maintenance of Antifriction Bearings. Good maintenance of antifriction bearings is essential to obtain a long, trouble-free service life. All persons who operate and repair farm equipment should obtain a bearing-maintenance handbook from a bearing manufacturer. These handbooks describe and illustrate replacement of bearings; their care, cleaning, and selection; and the use of lubricants. Many sealed antifriction bearings are used on farm equipment.

Bushings. A bushing is a replaceable lining for a bearing. It may consist of wood, babbitt, bronze, chilled iron, or other material. Figure 5-11 shows two types of bearing bushings with different types of grooves for distributing the oil along the shaft.

Keys. *Keys are of two kinds: first, those that fit into a slot in both the shaft and pulley, holding the two firmly together and causing them to* turn as a unit; second, the cotter or split keys that are put through a hole in the end of a bolt or pin to hold the nut and washer on.

Bolts. The great variety of bolts used in the construction of farm machinery can be classified as follows: machine, carriage, stove, and plow bolts.

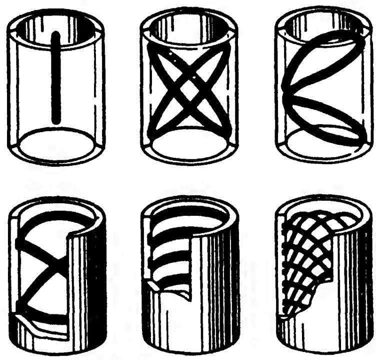
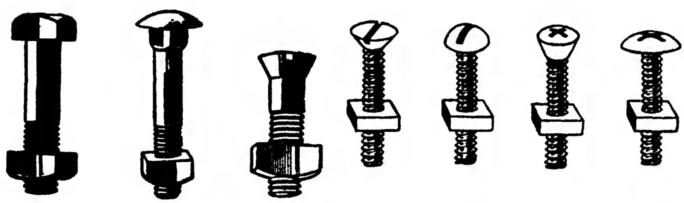


Fig. 5-11. Two types of bearing bushings: *top,* straight bushings showing types of grooves for oil; *bottom,* types of grooves for graphited oilless bearing



A B C D E F G

Fig. 5-12. Types of bolts: *A,* machine; *B,* carriage, *C,* plow; *D–G,* stove.

Machine bolts are used for holding two pieces of metal together. They have a square or hexagonal head with the stem of the bolt fitting into the head without any change of diameter, as Fig. 5-12.

Carriage bolts (Fig. 5-12), unlike machine bolts, have a rounded or oval-surfaced head with a square shoulder underneath extending out some half an inch, varying according to the size of the bolt.

Plow bolts may have many different kinds of heads, but practically all of them have from one to four shoulder-like points that fit into a groove prepared for them in whatever material they are placed. The undersides of the heads of plow bolts are always countersunk (Fig. 5-12) so that the head can go deep enough into the material to fit flush with the surface. Such bolts are used for holding plowshares.

Stove bolts, as shown in Fig. 5-12, are rather short bolts having threads running down close to the head, which may be either flat or round. Most stove bolts also have a slot cut across the heads so that screwdrivers can be used to prevent them from turning. This type of bolt is used for bolting thin metal together. Some special bolts are shown in Fig. 5-13.

Nuts. The most common types of nuts used on farm machinery are shown in Fig. 5-14. The square nut is used on the cheaper machines, and the hexagon nut is used on the higher class machines. Castellated nuts are used where vibration is likely to cause the nut to work loose. Wing nuts are used where it is necessary to remove a part frequently. Lock nuts are constructed so that they automatically lock themselves in place.

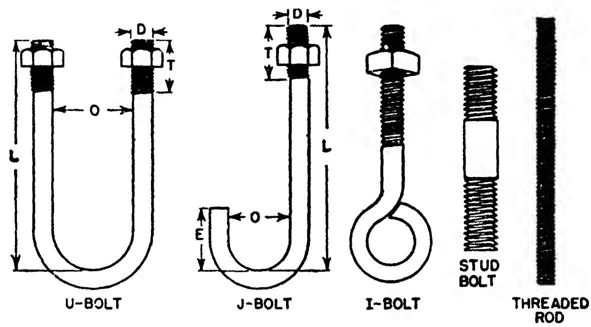


Fig. 5-13. Types of special bolts.

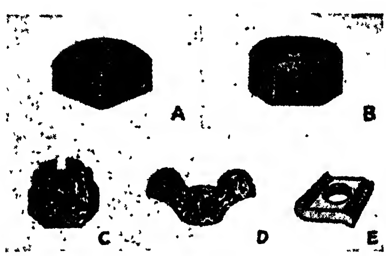


Fig. 5-14. Types of nuts: *A,* square; *B,* hexagon, *C,* castellated; *D,* wing; *E,* square lock.

Screws. Many types of screws are also used in the construction of farm machinery. They may be classified as follows: set, cap, lag, and wood.

Setscrews (Figs. 5-15 and 5-17) may have several different shapes for the point. They are so called because they extend through the collar, allowing the point to come in contact with the shaft so that the collar and shaft will be fastened rigidly together and turn as a unit. They are also used in the same way to prevent various parts from moving out of place.

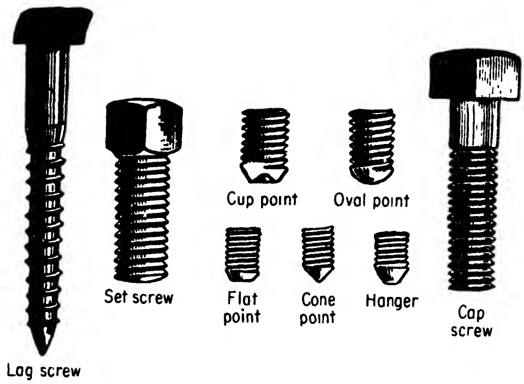


Fig. 5-15. Types of screw points, lag and cap screws.

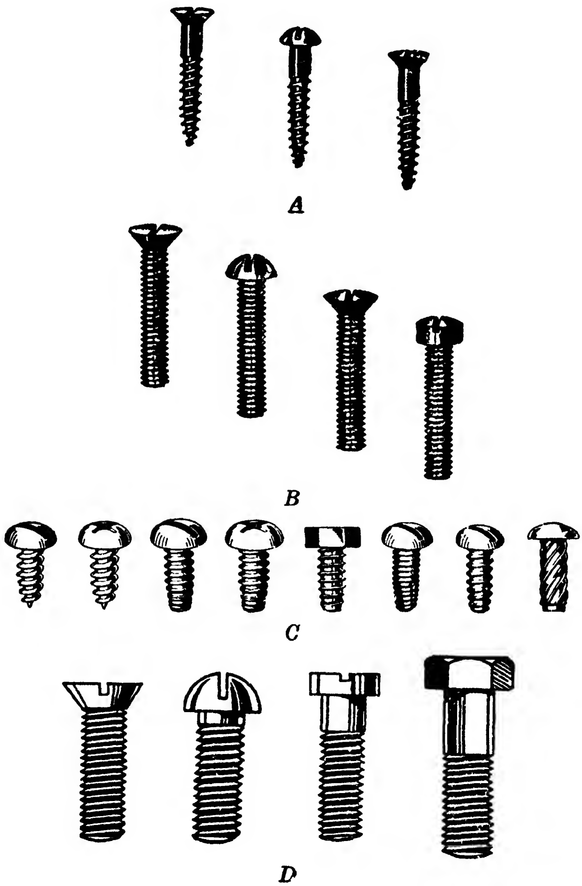


Fig. 5-16. Types of screws: *A*, wood; *B*, machine, *C*, self-threading or tapping; *D*, cap.

Cap screws (Fig. 5-16) may have square, hexagonal, flat, or button types of heads. Such screws resemble closely a machine bolt with the exception that they do not have a nut on the threaded end; instead, the end passes through whatever it is to hold into a threaded hole which serves as a nut, for example, the cylinder head of an automobile.

Lag screws (Fig. 5-15) have heads like a machine bolt, while the other end is sharp. The threads are coarse and similar to an ordinary wood screw. They are used to attach machinery to floors or beams. The coarse threads, when started, will draw themselves into the wood as the screw is turned with a wrench.

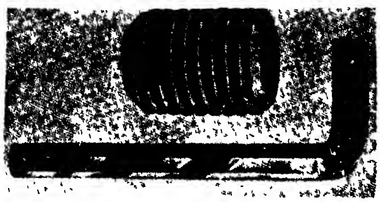
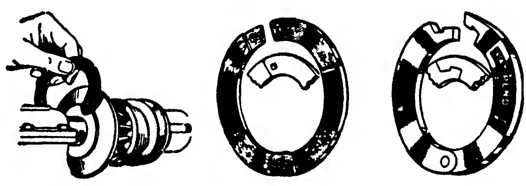


Fig. 5-17. Hollow-head setscrew and wrench.



A B

Fig. 5-18. Quick-repair washers: *A*, side-latch; *B*, overlatch.

Wood screws, unlike lag screws, are rather small and have slots across the head so that a screwdriver can be used to force them into the wood. (Fig. 5-16).

Washers. Different kinds of washers are used extensively in connection with bolts in farm machinery. They may be used on the end either beneath the head of the bolt or beneath the nut. Washers are of various kinds as follows: flat malleable-iron, cast-iron, wrought-iron, and spring-lock washers. There is very little difference between malleable- and cast-iron washers, both being rather thick, oftentimes ½ inch, and placed where there is a considerable amount of wear. Wrought-iron washers are round discs with holes in the center to allow their being placed under the nut. Lock washers are made of spring steel with one side split from the edge to center of the hole. The ends of the split parts are turned in such a manner that they will allow a nut to be turned down easily but resist

any effort to turn it off. Quick-repair washers are shown in Fig. 5-18. A plastic liquid material applied to nut and bolt for use as a liquid lock washer is available.

Springs. Springs (Fig. 5-19) play an important part in the operation of farm machinery. Extension springs aid in lifting and adjusting heavy im-

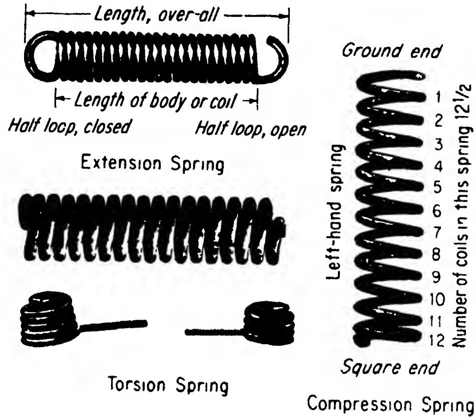


Fig. 5-19. Types of springs

plements. Compression and torsion springs facilitate the operation of certain parts of a machine.

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QUESTIONS AND PROBLEMS

1. Explain the function and application of a cam.
2. What is the difference between friction and antifriction bearings?
3. What kind of bearings need bushings?
4. Where are tapered roller bearings used?
5. Enumerate the various type of bolts, nuts, and screws.
6. What nonmetallic material can be used to lock nuts on bolts?

LUBRICANTS AND LUBRICATION

6

Probably the chief cause of machinery wearing out is improper and insufficient lubrication. Much of this trouble can be traced to the negligence of the operator, the poor construction of bearings, and the failure to provide adequate means of conducting the lubricant to the bearing units. Lubrication is needed because of friction.

Friction. Friction is that force which acts between two bodies at their surface of contact to resist the sliding of one body on the other. When one object is being dragged along upon another object, friction between the two tends to stop the one that is being dragged. When one surface rests upon another, there is a tendency for the inequalities of the one to fit into those of the other, causing an interlocking not unlike that produced by putting the cutting edges of two saws together. If such interlocking has occurred, it is possible to move one body over the other only by separating them or by tearing off the interlocking surfaces. No matter how smooth surfaces may be, there are still some elevations and depressions remaining which will permit a small degree of interlocking.

Rolling Friction. When one body rolls upon another, the friction is much less than when one body slides upon another. The resistance in this case is called the *rolling resistance* or *friction*. This can readily be demonstrated by attempting to carry as much upon a sled which has no wheels as upon a wagon or other vehicle mounted on wheels. Many farm implements are now using some type of antifriction bearing in the form of balls or rollers to diminish the amount of friction, which materially increases the efficiency of the machine. Friction in moving parts of machinery

causes wasted energy, and it is, therefore, desirable to reduce it to the smallest possible amount. However, in clutches or to prevent slippage of belts on pulleys, friction is necessary and useful.

Lubrication as a Remedy for Friction. Lubrication tends to reduce friction. The theory of the action of lubrication is that a thin film of the lubricant adheres to the bearing and another to the shaft, completely separating the metal surfaces. Then, these films slip one on the other, which reduces the amount of friction. This is because the friction between the films of lubricants is much less than that between the metal parts. A lubricant may act in different ways in reducing the amount of friction: first, by changing the greater resistance of metal to metal to the relatively small resistance of oil over oil; second, by filling up the small depressions in

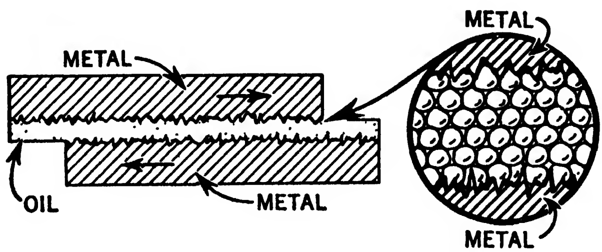


Fig. 6-1. How a lubricant keeps two pieces of metal apart.

the two frictional surfaces and in this way preventing the so-called *interlocking* (Fig. 6-1).

Forms of Lubricants. Lubricants are available in three forms: fluid oils, semisolids, and solids. Fluid oils are those that flow freely, such as gas-engine cylinder oils and oils used foı lubricating various bearings by means of oil holes or oil cups. Semisolids include tł , soft greases, such as transmission and differential grease. So.. d lubricants consist of graphite and mica. Of these forms, soft greases and oils are most generally used to lubricate farm implements.

Kinds and Sources of Lubricants. All lubricants have three general sources: animal, vegetable, and mineral. Animal oils are lard, tallow, and fish oils. Vegetable oils are cottonseed oil, castor oil, olive oil, and linseed oil. Mineral oils are oils obtained by refining crude petroleum. Of all these, mineral oils are the most universally used on the farm because they can withstand higher temperatures without breaking down.

Manufacture of Lubricants. The diagram in Fig. 6-2 shows the steps in the refining process and the points of extraction where fuels; light, medium, and heavy oils; and the extra-heavy lube stock are obtained.

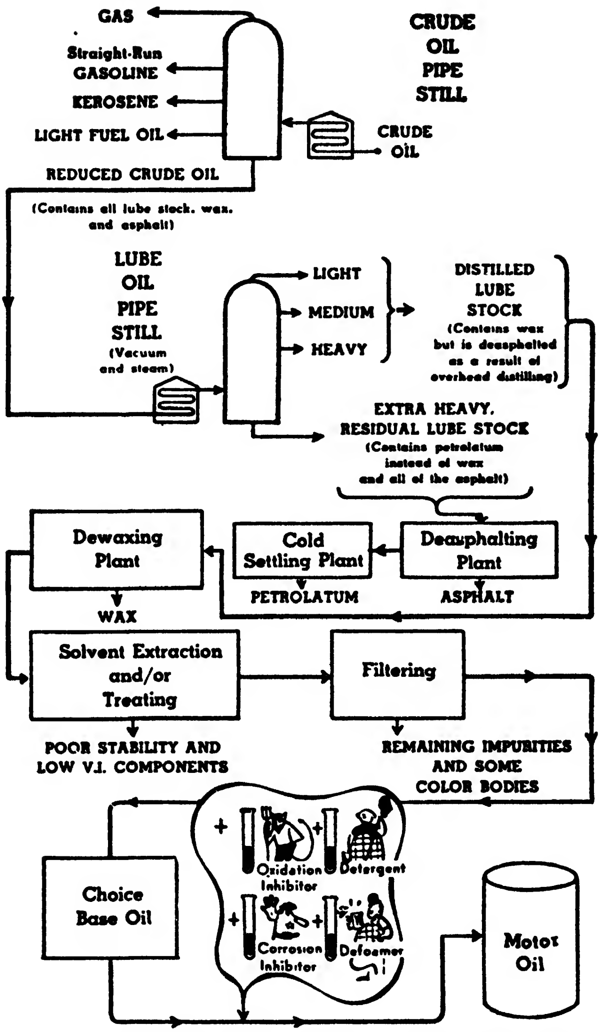


Fig. 6-2. Diagram showing refining process and the points where the oil and greases are obtained. (*Standard Oil Company.*)

SERVICE CLASSIFICATIONS OF AUTOMOTIVE ENGINE LUBRICATING OILS

Prior to 1952, automotive types of engine oils were classed as regular, premium, and heavy-duty. The American Petroleum Institute has set up a new system of service classification, designations, and definitions for

automotive types of engine lubricating oils. The three basic factors involved are:

1. The type of engine
2. The kind of service
3. The nature of the fuel

The two basic engine types are the *gasoline* or *other spark-ignition engines* and the *diesel engines*. Oils for the gasoline and spark-ignition engines are given the designation of *M*, while the oils for the diesels are designated as *D* oils.

Three kinds of service are set up for the gasoline or other spark engines. These are:

1. Service ML—light and favorable
2. Service MM—moderate to severe
3. Service MS—unfavorable or severe

The American Petroleum Institute (API) defines and explains the three classes of services as follows:

Service ML. "Service typical of gasoline or other spark-ignition engines operating under light and favorable conditions, the engines having no special lubricating requirements and having no design characteristics sensitive to deposit formation."

Service MM. "Service typical of gasoline and other spark-ignition engines operating under moderate to severe service conditions, but presenting problems of deposit or bearing corrosion control when crankcase oil temperatures are high."

Service MS. "Service typical of gasoline and other spark-ignition engines, where there are special lubrication requirements for deposit or corrosion control. The severity of these special lubrication requirements varies with the engine design factors which in themselves may vary with different makes and models, with fuel characteristics, and particularly with engine operating conditions."

Under the MS service, there are two types of severe service or operating conditions, namely, (1) start-and-stop service and (2) high-temperature service.

Diesel-engine Services. Service DG—"Service typical of diesel engines in any operation where there are no exceptionally severe requirements for wear or deposit control due to fuel or engine design characteristics."

Service DG, DM, and DS. "Service typical of diesel engines operating under extremely severe conditions or having design characteristics or using fuel tending to produce abnormal wear or deposits."

Markings on Containers. Oil manufacturers are to indicate the service or

services of an oil, for service ML, for service MM, and so forth. The container label shows the type of service (Fig. 6-3). If an oil is suitable for more than one service, it may have a multiple designation as "For services MS-DG." This designation means that such an oil is satisfactory for the most severe gasoline-engine service and also for the still different requirements of general diesel-engine service.

Grades of Engine Oils. The Society of Automotive Engineers grades engine oils according to their body or viscosity as SAE 5W, SAE 10W, SAE 20-20W, SAE 30, SAE 40, and SAE 50. The W after the number in-

Fig. 6-3. Marking for oil container showing type of service.

dicates that the oil is suitable for winter use. The 20-20W is an oil suitable for both summer and winter use.

GEAR LUBRICANTS

The American Petroleum Institute gives three definitions of gear lubricants, as follows:

1. *Regular-type* gear lubricant. "This term designates gear lubricants generally suitable for use in automotive transmission and in most spiral-bevel and worm-gear differentials."

2. *Worm-type* gear lubricant. "This term designates gear lubricants generally suitable for use in truck-type worm-gear axles under severe conditions of service."

3. *Mild-type E.P.* (extreme pressure) gear lubricant. "This term designates gear lubricants having load-carrying properties suitable for many automotive transmissions and spiral-bevel differentials under severe conditions of speed and load."

The SAE viscosity grade for gear lubricants is given in Table 6-1.

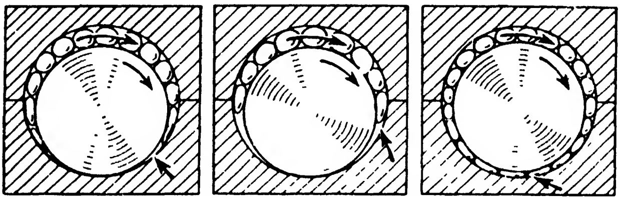
In general, SAE 140 is recommended for high-temperature summer operation, SAE 90 for moderate-temperature conditions, and SAE 80 for severe low-temperature conditions. Manufacturers of tractors and equip-

ment usually recommend the grade of lubricant to use for any particular gear-drive mechanism.

TABLE 6-1. SAE CLASSIFICATION OF GEAR LUBRICANTS

SAE viscosity no.	Viscosity range, Saybolt Universal	Consistency must not channel in service at °F.
80	100,000 sec. at 0°F., max.	Minus 20
90	800 to 1500 sec. at 100°F.	Zero
140	120 to 200 sec. at 210°F.	Plus 35
250	200 sec. at 210°F., min.	

Viscosity. The viscosity of an oil is a measure of its *fluidity* or *flowability* at definite temperatures. The viscosity is usually determined at temperatures of 100 and 210°F. An oil to be tested is placed in a viscosimeter or the Saybolt apparatus, consisting of a specially shaped vessel



A
Not enough body Oil can't support shaft

B
Too high viscosity Oil can't "get in"

C
Correct body Correct viscosity

Fig. 6-4. Effects of viscosity in lubricating a bearing.

equipped with a standard size orifice, or opening, at the lower end. This vessel is surrounded by a liquid bath for temperature control. Thermometers are placed in both the oil and the bath liquid. The orifice is kept closed with a cork until the two liquids have been heated to 100 or 210°F. The cork is removed and the oil permitted to flow into a graduated flask. The time, expressed in seconds, required for 60 cubic centimeters of oil to flow through the orifice is called the viscosity of the oil at the temperature tested. The viscosity at other temperatures can be calculated. A special viscosity-index chart has been worked up for the chemist. The effect of viscosity on lubricating a bearing is shown in Fig. 6-4.

GREASES

The American Society for Testing Materials defines a petroleum lubricating grease as "a semisolid or solid combination of a petroleum product

and a soap, or a mixture of soaps, with or without fillers, suitable for certain types of lubrication." In ancient times a grease made of animal fat was probably used to lubricate the axles of chariots. Mineral oil grease was developed soon after the discovery of oil in 1859. Early farm machinery which was drawn by horses had few moving parts, and almost any type of grease would suffice to reduce friction. Modern power-operated machinery has many bearings carrying light to heavy loads. Some parts operate at high speeds and high temperatures and require special high-quality greases. A water-repellent grease is required for

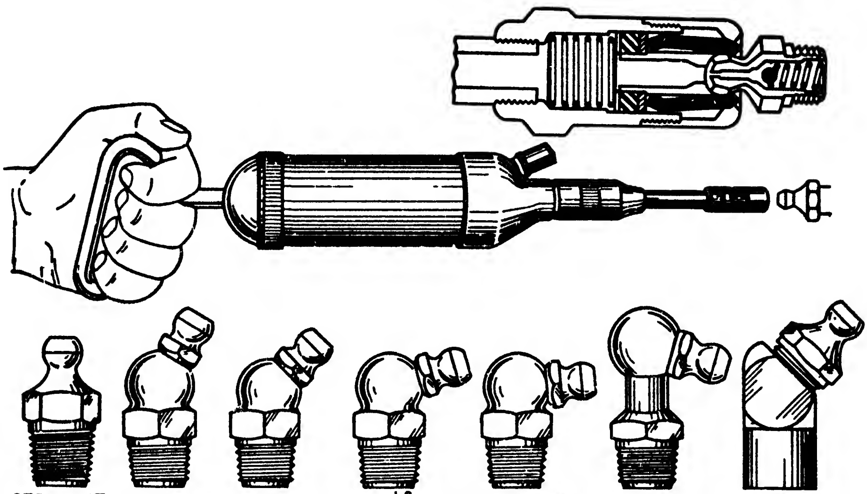


Fig. 6-5. Hydraulic hand-push grease gun and fittings, showing cross section of nozzle and fitting. (*Alemite Division, Stewart-Warner Corp.*)

water pumps, a soda-base grease of spongy or fibrous texture for wheel bearings and universal joints, a cup grease for distributor shafts, and a soft tacky grease for chassis joints.

Classes of Greases. Greases as indicated above are classed according to the use and application for which they are specially suited. There are many types, but the most common are (1) chassis greases, (2) wheel-bearing greases, (3) water-pump greases, (4) universal-joint greases, and (5) the cup greases. The greases used most are the chassis and the wheel-bearing greases. The chassis grease is designed for pressure-gun application, while the wheel-bearing grease is generally packed in the wheel bearing by hand.

Grades for Greases. The National Lubricating Grease Institute has adopted six grade numbers which are an indication of firmness or hard-

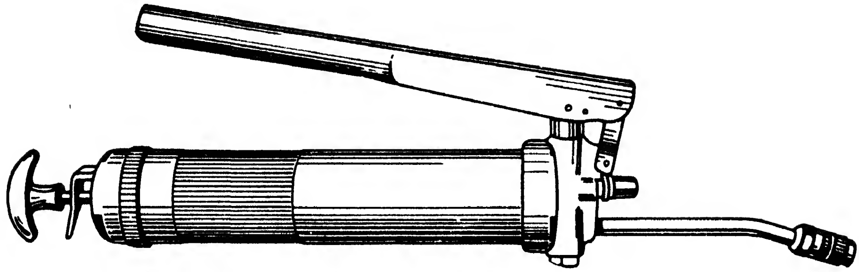


Fig. 6-6. Lever-type grease gun.

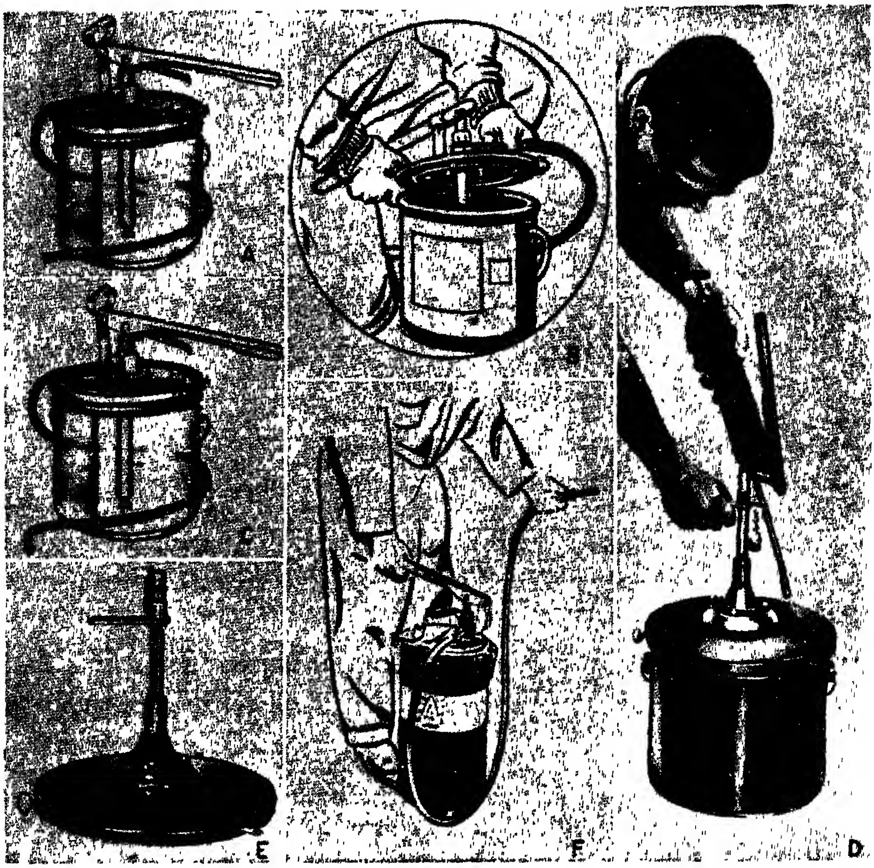


Fig. 6-7. Portable hand-tank grease guns and pails: *A*, interchangeable pail pump with hose; *B*, installing pail pump on pail; *C*, interchangeable pail pump for gear oils; *D*, interchangeable pail hand-gun loader; *E*, detachable lid for hand-gun loader; *F*, portable grease bucket with pump. (*Alemite Division, Stewart-Warner Corp.*)

ness of the grease, as shown in Table 6-2. The ASTM worked penetration at 77°F. is shown in relation to the NLGI grade number.

TABLE 6-2. GREASE GRADES AND WORKED PENETRATION

NLGI no.	*ASTM worked penetration*
0	355–385
1	310–340
2	265–295
3	220–250
4	175–205
5	130–160

The penetration test consists of dropping a metal cone of standard size and weight into a worked grease at a specified temperature (usually 77°F.) and measuring the penetration of the cone after a specified time

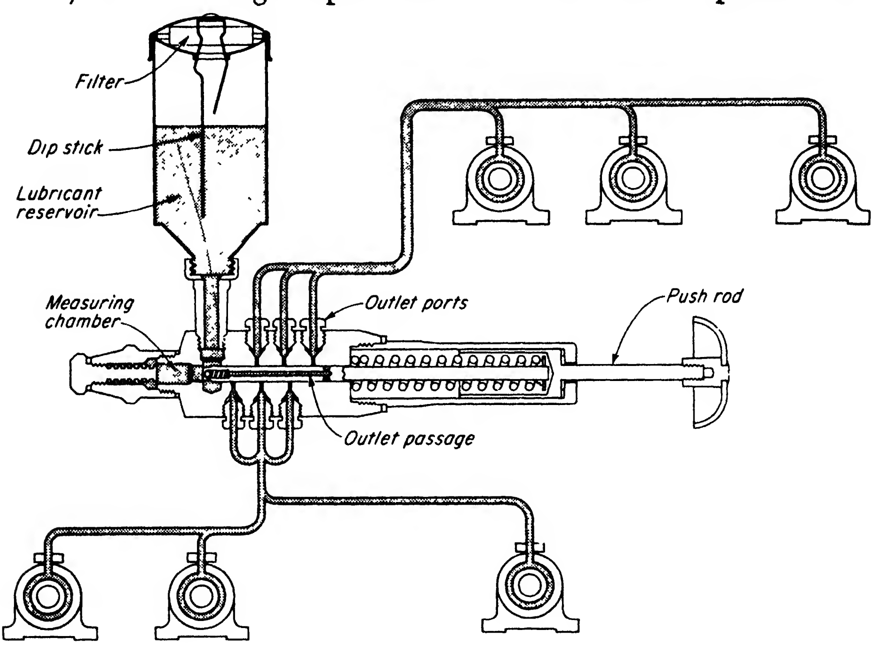


Fig. 6-8. Arrangement of multiple feed lines that can be attached to the master hand-gun lubricator shown at the center. (*Lincoln Engineering Co.*)

interval. The consistency or hardness of greases ranges from No. 0, very soft, to No. 5, a very hard grease. The color of greases varies from light red to pitch black according to the ingredients used.

Methods of Applying Greases. Some greases are applied by hand with a paddle, swab, or brush to gears, chains, and wire rope. Slow-moving bearings can be lubricated by placing the grease in cups of the screw-down, spring-loaded, and automatic types.

All well-designed modern farm machinery has high-pressure grease fittings at the points requiring lubrication. The grease is applied through the fitting with high-pressure grease guns (Figs. 6-5 to 6-8). The proper lubrication of farm machinery bearings and moving parts is one of the most important factors in care and maintenance. Many manufacturers are installing central lubrication systems called *multi-luber systems*. The system operates by diaphragm pumps activated by vacuum from the engine. On self-propelled machines the system is operated by pressing a push button on the instrument panel. A light on the panel indicates when the lubrication cycle has been completed. Hand-push-plunger multi-luber systems are available for machines not equipped with power units (Fig. 6-8). Companies manufacturing lubricants have available lubrication guides showing all the points on the machine requiring lubrication and the kind of oil or grease recommended for each fitting.

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QUESTIONS AND PROBLEMS

1. Define friction and discuss its advantages and disadvantages.
2. Enumerate the forms, kinds, and sources of lubricants.
3. Explain the API system of service classification of lubricants for gasoline and spark-ignition engines; name the different kinds of service and give the main features of each service.
4. Explain the API service systems for diesel engines, and give the main features of each system.
5. Discuss the SAE grades of engine oils and gear lubricants. What is meant by an *EP* gear lubricant?
6. Explain the meaning of oil viscosity, and describe how it is measured.
7. Give a definition for grease, and list the main types according to use.
8. Explain the NLGI grades of grease.
9. Discuss the various methods of applying greases to farm equipment. What is meant by high-pressure lubrication?
10. Describe a multi-luber system.

HYDRAULIC POWER LIFTS FOR FARM EQUIPMENT

7

Farm equipment prior to the nineteenth century era was animal drawn, guided by hand, and lifted manually. Later, when equipment was mounted on wheels, levers were used to raise and lower the working units. The first mechanical power lift was developed for the trailing-type tractor-drawn plows about 1910 (Fig. 7-1). The tractor power lift was developed about 1930 to raise and lower planters and cultivators mounted on the row-crop tractor. The use of hydraulic power for lifting tractor-mounted equipment was introduced in 1935. Hydraulic power lifts are now used for raising, lowering, and controlling almost all types of field equipment, ranging from the small plow to the platform of a grain combine and the drums of cotton-picking machines. In fact, if it were not for the hydraulic lifts, these heavy units would be extremely difficult to operate.

The extensive use of hydraulic lifts and controls makes it essential that the operator of modern farm equipment have an understanding of the fundamental principles of power-lift hydraulics.

Fundamentals of Hydraulics. There are several branches of hydraulics, but the branch applicable to farm equipment deals with enclosed liquids under pressure. The fundamental law of hydrostatics, or the mechanics

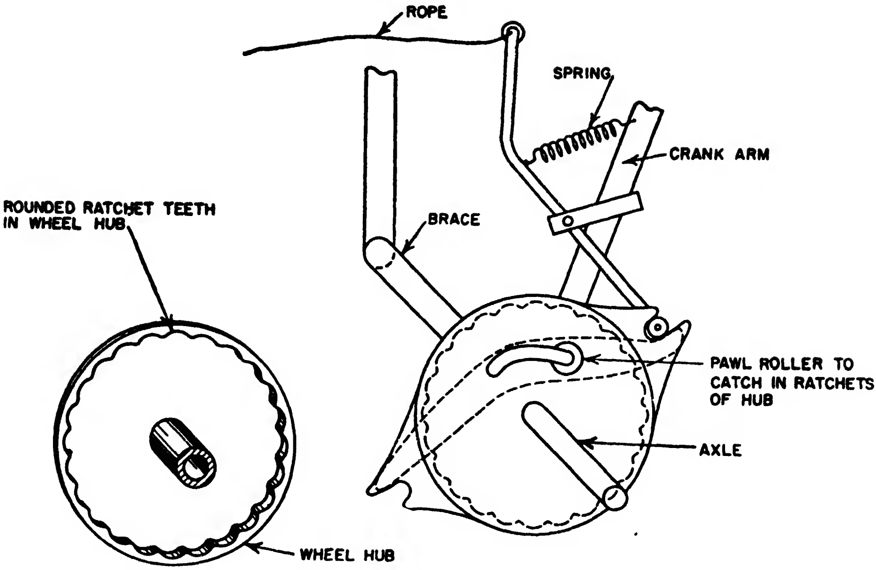

Fig. 7-1. Mechanical power lift for plow.

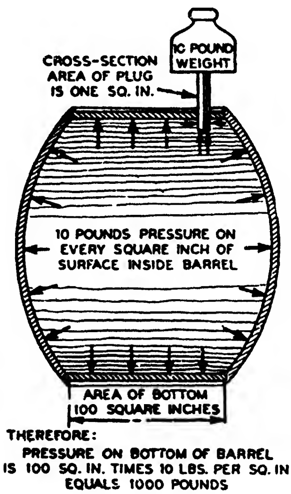

Fig. 7-2. How pressure on a liquid distributes pressure in all directions of its enclosure case. (*International Harvester Company.*)

of fluids, was defined by Blaise Pascal[1] in 1653 as follows: "Pressure applied to an enclosed fluid is transmitted equally and undiminished in all directions to every part of the fluid and of its restraining surfaces." The application of this law is shown in Figs. 7-2 and 7-3. In Fig. 7-3 is a

[1] Frank L. Robeson, *Physics*, The Macmillan Company, New York, 1943.

1-pound weight acting on 1 square inch of liquid which is counterbalanced by a weight of 10 pounds on 10 square inches of liquid. There is a 1-pound pressure for each square inch of surface on all sides of the container. The 1-inch piston must move 10 inches to move the 10-square-inch piston 1 inch.

Oil Pumps. Pumps are required in the operation of hydraulic controls to draw the oil from a reservoir and force it into a cylinder. The pump may be of three types, namely, *gear*, *vane*, and *piston*.

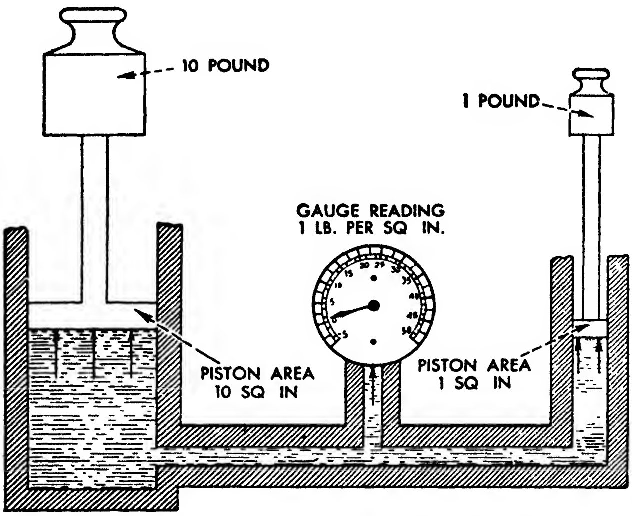

Fig. 7-3. A simple hydraulic system with a 1-pound weight on 1 square inch has the same pressure per square inch as the 10-pound weight on the piston resting on 10 square inches of liquid. There is also a 1-pound pressure on the gage. (*International Harvester Company.*)

A typical rotary double-gear pump consists of two closely meshing gears enclosed in a tight, compact housing. There are intake and discharge ports on opposite sides of the housing. When they rotate as indicated in Fig. 7-4, the oil is drawn in through the intake port and caught in the spaces between the gear teeth and the housing. The oil is carried around by the gear teeth and forced out through the discharge port. When the gears are rapidly rotated, a partial vacuum is created which draws oil from the reservoir.

A vane-type oil pump is shown in Fig. 7-5. The rotor has a number of radial slots into which movable vanes are fitted. As the rotor revolves, the vanes are forced outward by centrifugal force and oil pressure against the surface of an oval-shaped ring. The vanes follow the inside cam contour as they rotate. The oval ring is so shaped that two opposing pump-

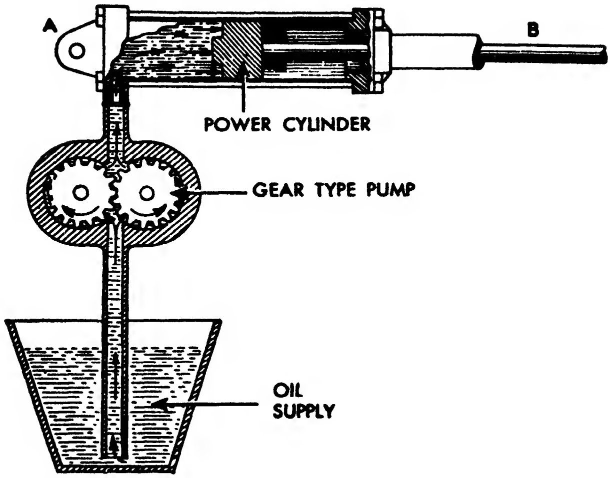

Fig. 7-4. Simple diagram showing how a gear pump pumps oil from a reservoir of oil to a power cylinder. (*International Harvester Company.*)

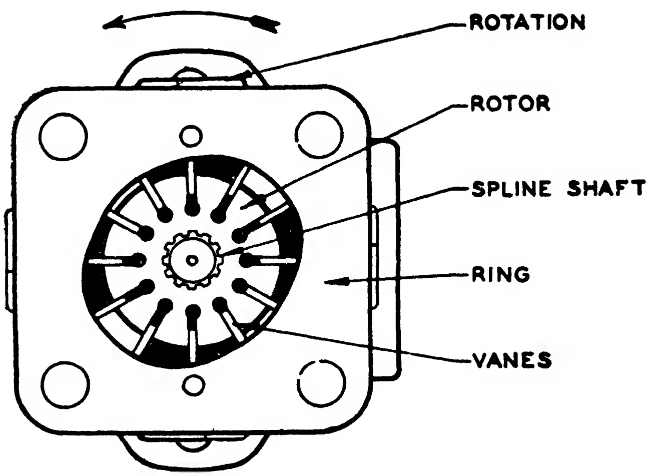

Fig. 7-5. End view of vane-type oil pump with oval ring and rotor with sliding vanes. (*Vickers, Inc.*)

ing chambers are formed on opposite sides of the rotor. The oil is drawn in on one side and forced out on the opposite side. The pump gives a continuous flow of oil when the tractor engine is operating.

Piston oil pumps may have as many as four small plunger pistons operated, in most cases, by cams. A variable delivery of oil can be obtained by closing the ports to one or more of the pistons.

When the pump and the cylinders are connected (Figs. 7-6 and 7-7) by means of steel pipe or high-pressure hose, oil can be pumped into

power cylinders located either near or at a considerable distance from the pump. The oil reservoir and pump may be located at some point within the tractor housing or at some convenient place outside the housing (Fig. 7-8). In either case, the hydraulic pump and system become a component part of the tractor. As oil pumps operate continuously, a by-pass is essential to permit oil to return to the reser-

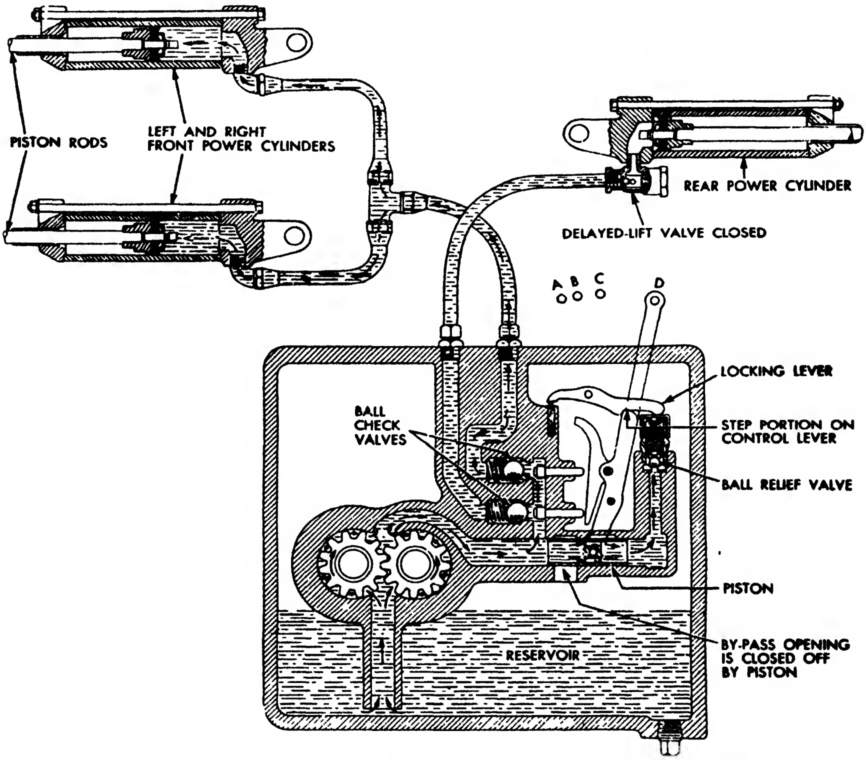

Fig. 7-6. Schematic diagram of a hydraulic-lift system where oil is being pumped into two lifting cylinders. At this stage the pressure is not high enough to open the delayed lift valve on the rear cylinder. (*International Harvester Company.*)

voir when no pressure is required in the lifting cylinders. When implements are changed from one tractor to another, care should be taken to have the same type of oil. Mixed oils may affect the O rings in the hydraulic cylinders.

Hydraulic Cylinders. Hydraulic cylinders are also called rams and jacks. When hydraulic force is applied through especially designed cylinders and connections, farm equipment can be lifted, lowered, and controlled easily. The ASAE standards give the dimensions and specifications of hydraulic cylinders for remote control of trailing farm implements. The

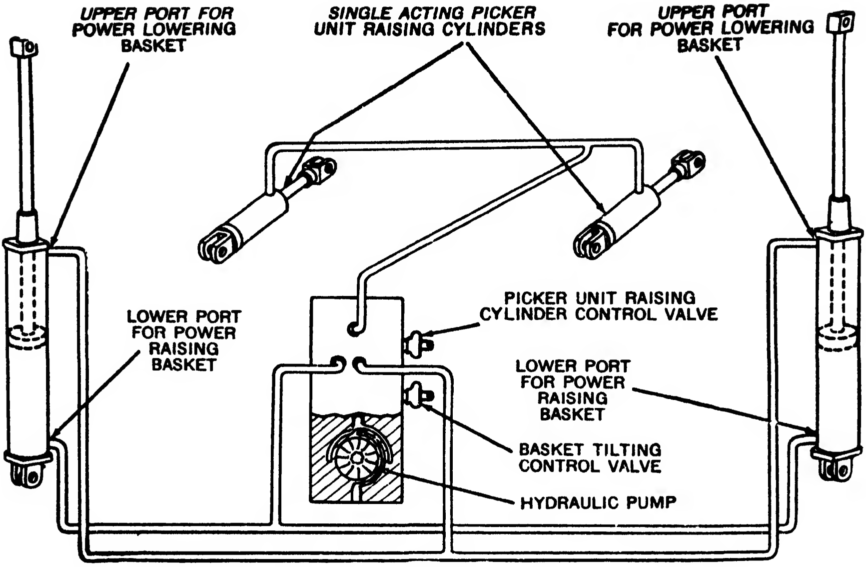

Fig. 7-7. Schematic diagram of hydraulic-lift system for cotton picker, showing hydraulic pump, oil reservoir, a system of passages and valves to direct the flow of oil to raise the cotton-picker drums and tilt the cotton basket. (*Deere & Co.*)

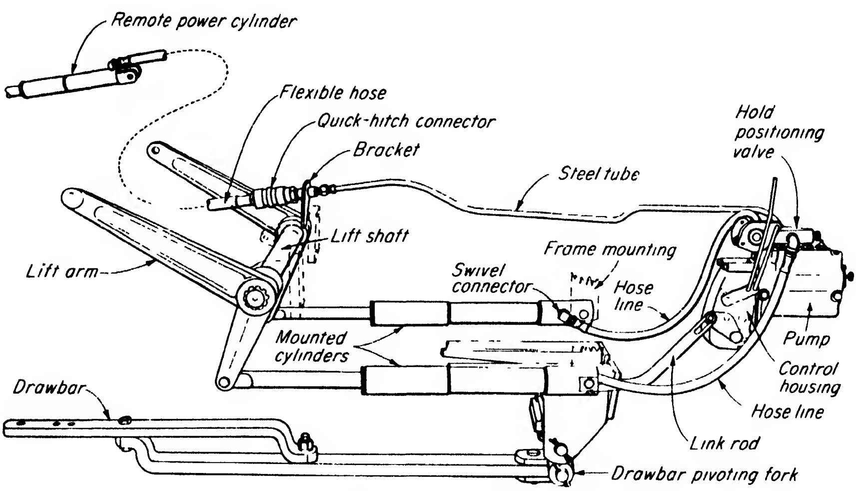

Fig. 7-8. Schematic diagram showing hydraulic oil pump, hose lines, and power cylinders for operating lift shaft and crank arms, mounted as component parts of the tractor, and optional use of a remote-control cylinder. (*Allis-Chalmers Mfg. Co.*)

recommended length of stroke for such cylinders is 8 inches. Figure 7-4 shows how pressure is exerted on a piston inside a cylinder when oil is pumped into the cylinder. A cylinder 3 inches in diameter is approximately 7 square inches in cross-sectional area. Therefore, if oil is being

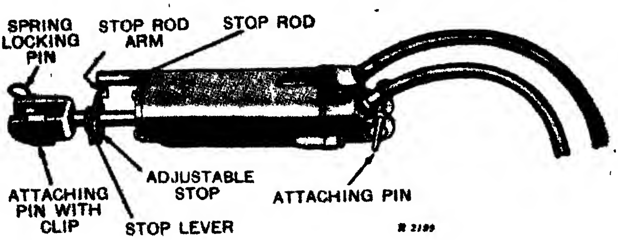

Fig. 7-9. Remote-control hydraulic cylinder with parts named. (*Deere & Co.*)

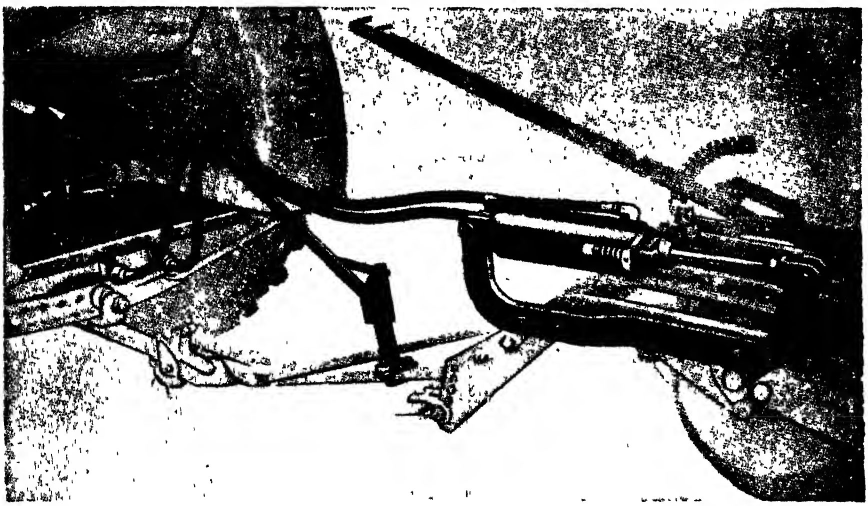

Fig. 7-10. Portable hydraulic-lift cylinder equipped with stop yoke attached to trailing plow so that adjustments can be made for uniform plowing depth. (*J. I. Case Company.*)

forced into the cylinder with a pressure of 800 pounds, the pressure against the face of the piston is 800 × 7, or 5,600 pounds. If the cylinder is fastened to a rigid part of a machine at *A* and the piston rod *B* connected to a crank arm, the machine can be lifted with 5,600 pounds pressure. Figure 7-6 shows a schematic diagram of how hydraulic power cylinders can be used to lift units, such as cultivator gangs.

Figures 7-9 and 7-10 show two-way or double-action cylinders designed so that oil pressure can be applied to either side of the piston and thus exert power in two directions. This type of cylinder is used to

control plowing depth and to angle and de-angle tandem disk-harrow gangs. Stop yokes on hydraulic cylinders are provided to shorten the length of the cylinder stroke from the full standard 8 inches to 0 on some

TABLE 7-1. CYLINDER PRESSURE OR THRUST REQUIREMENTS FOR MOLDBOARD PLOWS EQUIPPED WITH 12-, 14-, AND 16-INCH BOTTOMS

Number of bottoms	Maximum cylinder thrust, lb.	
	Traveling	Stopped
2	4,275	4,700
3	4,050	6,250
4	6,300	8,500
5	9,950*	11,500*

* The disproportionate increase in the cylinder thrust necessary to raise the five-bottom plow reflects the heavy duty imposed by implements built with sufficient strength for operation with crawler tractors. W. H. Worthington and J. W. Seiple, *Agr. Engin.*, **33**(5):273–276, 1952.

TABLE 7-2. CYLINDER THRUST REQUIREMENTS FOR DISK PLOWS 24, 26, AND 28 INCHES IN DIAMETER

Number of disks	Maximum cylinder thrust, lb.	
	Traveling	Stopped
2	1,030	1,770
3	2,880	2,730
4	2,450	2,900
5	2,800	4,575
6	9,050*	8,850*

* The severe lifting requirement of the heavy-duty-type implements is evidenced. W. H. Worthington and J. W. Seiple, *Agr. Engin.*, **33**(5):273–276, 1952.

cylinders, as desired. Where several inches of movement are required, long hydraulic power cylinders with long piston rods can be used.

Tables 7-1 and 7-2 show the maximum pounds pressure required in a hydraulic cylinder to lift various sizes of moldboard and disk plows. The maximum pressure to angle different sizes of tandem disk harrows is shown in Table 7-3. The cylinder pressure necessary to lift or control the implements is shown for both moving and stopped positions.

Worthington and Seiple found that the minimum values of drawbar horsepower per plow bottom form the most consistent index of power requirement for tractor sizes rated to operate two to five bottoms. Tractors of a given drawbar horsepower can operate larger and heavier imple-

TABLE 7-3. CYLINDER THRUST REQUIREMENTS FOR TANDEM OR DOUBLE-ACTION DISK HARROWS

Width of cut, ft.	Maximum cylinder thrust, lb.	
	Traveling	Stopped
6	1,960	2,680
7	3,090	2,670
7½	3,740	3,070
8	3,080	3,210
9½	1,900	2,400
10	5,280	5,000
10½	1,900	2,650
11½	2,100	2,950
12	2,250	4,000
14½	8,980	11,010

SOURCE: W. H. Worthington and J. W. Seiple, *Agr. Engin.*, **33**(5):273–276, 1952.

ments under favorable conditions than they can under unfavorable conditions. Therefore, it follows that any matching of tractor-drawbar performance with accompanying hydraulic-cylinder lifting effort may properly be on the basis of minimum tractor power and maximum cylinder thrust for each implement-tractor group as shown in Table 7-4.

TABLE 7-4. MINIMUM HYDRAULIC CYLINDER THRUST FOR VARIOUS IMPLEMENT-TRACTOR GROUPS

Implement-tractor group	Minimum cylinder thrust, lb.	
	Traveling	Stopped
2-plow group	4,500	5,625
3-plow group	6,000	7,500
4-plow group	7,500	9,375
5-plow group	10,000	12,500

Master Control Units. The master control mechanism that directs the flow of oil to the various power cylinders may be located either within the tractor gear case or at some convenient place outside the gear case. These units consist of a system of passages, control valves, check valves, regulator valves, safety valves, and pistons. These systems are called many different names, such as *touch-control, touch-o-matic, lift-all, power-trol,* and *power-pack.* These control units are assembled and installed at the factory. Control units are used on self-propelled grain combines and cotton-picking machines (Fig. 7-7).

Selective Control. The selective control of a hydraulic-lift system provides individual control of the right- and the left-hand-mounted units separately

and the front and the rear units separately. This is done by the use of delayed lift (Fig. 7-11) and retarding valves to regulate the flow of oil to and from the remote cylinder. In a master control system, the flow of oil to the various cylinders is regulated by opening and closing an arrangement of valves and passages.

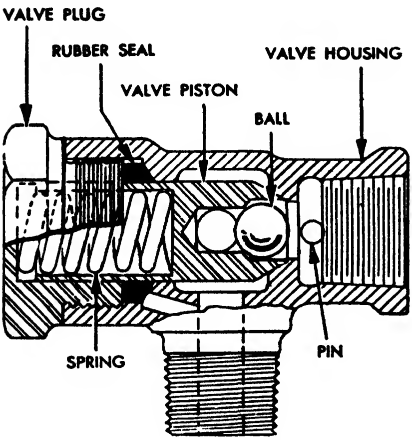

Fig. 7-11. A cross-sectional view of a delay lift valve. A pressure of 425 to 475 pounds per square inch is required to lift the valve off its seat and permit oil to flow into the cylinder. The valve is installed on the end of the hose next to the lift cylinder, as shown. (*International Harvester Company.*)

There are many types of master and selective control systems. Each manufacturer has a particular design and application of hydraulic power controls. The operator should obtain service literature for the make of his equipment and carefully study it before making adjustments. Major repairs should be done by a trained serviceman.

Accessories for Hydraulic Controls. When the oil pump and controls are located on the tractor and the hydraulic-lift cylinder at a remote distance on a trailing implement, high-pressure hose of sufficient length must be provided to permit required turns (Fig. 7-10). The hose should be of a quality to resist oil deterioration, to withstand high pressures, and to work at a wide range of temperatures. The data in Table 7-5 show the specifications for one make of hose.

TABLE 7-5. SPECIFICATIONS FOR HIGH-PRESSURE HOSE

Size	Hose I.D., in.	Min. burst pressure	Max. working pressure	Min. bend radii,* in.
4	3/16	12,000	1,500	1 15/16
5	1/4	10,000	1,500	2 3/16
6	5/16	9,000	1,500	2 5/8
8	13/32	8,000	1,500	4 5/8
10	1/2	7,000	1,500	5 1/2
12	5/8	6,000	1,500	6 9/16
16	7/8	3,200	800	7 3/8
20	1 1/8	2,500	600	9
24	1 3/8	2,000	500	10 1/2
32	1 13/16	1,400	350	13 1/4

* At maximum working pressure.

Should a trailing machine equipped with a remote-control hydraulic cylinder break away from the tractor, a safety breakaway coupling should be provided to prevent damage or breaking of the hose. A breakaway coupling is shown in Fig. 7-12.

The hose between the tractor and the implement should be provided with adequate supports to protect the hose.

When implements are interchanged frequently, much time can be saved by the use of snap-on hose connections. Special care should be taken to keep all hose connections clean. When disconnected hose is to

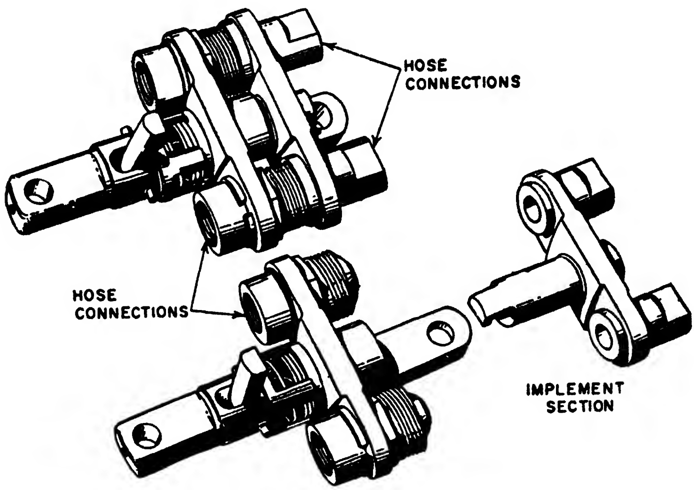

Fig. 7-12. Breakaway coupling for trailing equipment: *top,* shows coupling connected; *bottom,* shows tractor and implement sections separated. (*Aeroquip Corp.*)

be left unused, the ends should be wrapped with a rag to keep dirt and sand from getting in the hose. A grain of sand can cause serious valve trouble.

Hydraulic-Electric Lift. The company that developed this system terms it a *Hydra-Lectric* system. The operation is described as follows:

> Located within the fluid reservoir are one or two solenoid-actuated selector valves depending upon whether one or two cylinders are being used. Each selector valve has an up and a down "coiled" solenoid, arranged coaxially and having a common metal plunger. When either up or down solenoid is energized, it moves the solenoid plunger in a respective forward or backward direction. Through a crank arrangement, the plunger actuates a spool-type selector valve which opens and closes parts that control the direction of fluid flow to the cylinder to produce an outward or inward stroke of the piston rod. When the selector valve is

moved to a neutral position, the flow of fluid to the cylinder is shut off and is directed back to the reservoir. A spring and ball controlled interlock valve then traps the fluid leading to the cylinder and holds the piston rod in a stationary position.

The system can be used to control either mounted or trailing equipment.

Special Hydraulic Applications. Hydraulic cylinders have many applications in special jacks, truck and trailer box lifts, utility hoists, loading attachments, and steering aids.

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QUESTIONS AND PROBLEMS

1. Trace the development of power lifts.
2. Give the fundamental law of enclosed liquids.
3. A cylinder 10 inches in length and 10 inches in diameter is completely filled with oil. A pressure of 20 pounds is applied through an opening in the top. What is the total pounds pressure on the bottom?
4. Explain the action of a gear pump.
5. A gear pump is forcing oil into a cylinder 2½ inches in diameter and 8 inches in length at a pressure of 750 pounds. What is the total pounds pressure against the cylinder piston?
6. Explain the difference in action of a single- and a double-action cylinder. Give an application of the use of each type.
7. Explain the functions of a master control unit and what is meant by selective controls.

RUBBER TIRES FOR FARM EQUIPMENT

8

Numerous tests with tractors and other farm machines equipped with rubber tires reveal the relative advantages and disadvantages.

Advantages of rubber-tired tractors are (1) higher operating speeds, (2) less power required for the same load, (3) less fuel consumption, (4) decreased rolling resistance, (5) less vibration, (6) easier handling qualities, and (7) greater comfort for the operator.[1]

Disadvantages are (1) difficulty of holding on listed ground, (2) greater slippage on wet soil, (3) greater initial cost, and (4) possibility of punctures.

When used on other farm machines, such as combines, sprayers, and potato planters and diggers, rubber tires reduce the drawbar pull, the fuel consumed by the tractor, vibration, and dust. They also make transportation easier from field to field and along the highways.

Kinds of Rubber Tires. In general, rubber tires used on farm equipment can be divided into two classes, namely, *traction* and *free-rolling.*

Traction Tires. Traction tires have specially designed treads which grip the soil with sufficient bite to give a high degree of traction for pulling heavy loads with a minimum of slippage. Figure 8-1 shows several special-purpose traction treads. Traction tires are used on tractors and self-propelled equipment. They are designed to carry a load as well as give traction.

Free-rolling Tires. Tires of this type are also called *implement* tires. They are designed primarily to carry loads. The rib tread is constructed

[1] *Agr. Engin.*, 14(2):39, 1933; 16(2):45, 1935; and 17(2):73, 1936.

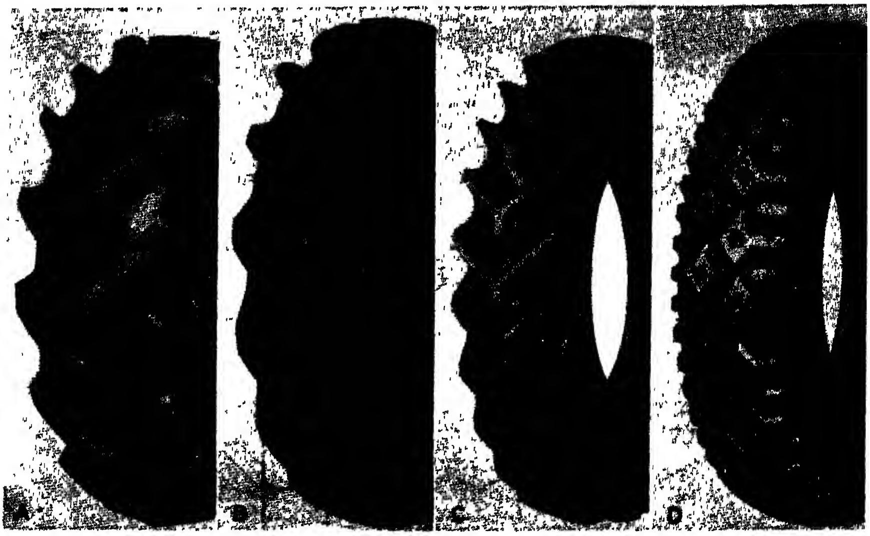

Fig. 8-1. Types of rear-wheel tractor tires: *A*, heavy-duty deep tread; *B*, standard-type farm tread; *C*, cane-field special tread; *D*, general-purpose and industrial tread. (*Goodyear Tire and Rubber Company.*)

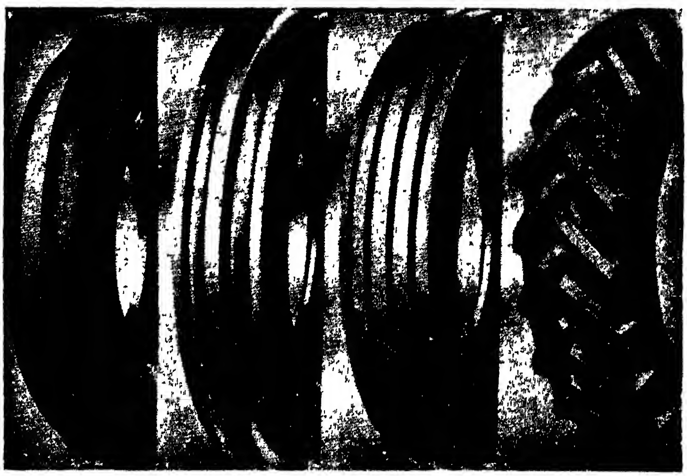

Fig. 8-2. Free-rolling-implement rib tires and tire with tread for moderate traction. (*Goodyear Tire and Rubber Company.*)

to aid the wheel in rolling straight forward and to prevent as much side-slip as possible (Fig. 8-2). Where moderate traction is required in an implement tire, the tread has a lug design of medium height (Fig. 8-2). Such tires are used on manure spreaders and other machines that require ground traction for their operation.

Agricultural Tire Code. The Tire and Rim Association and Rubber Manufacturers Association have developed and approved a code numbering system for tires, as shown in Table 8-1. The *F*, *R*, and *G* series are traction-type tires, while the *I* series are implement tires. This code designation is stamped on the side wall of all tires just under the size and ply rating.

TABLE 8-1. AGRICULTURAL TIRE CODE DESIGNATIONS

Tractor tires	Desig.	Implement tires	Desig.
Front:		Rib implement	I-1
Single rib	F-1	Moderate traction	I-2
Triple rib	F-2	Traction implement	I-3
Industrial	F-3	Plow tail wheel	I-4
Rear:		Hillside combine	I-5
Farm	R-1	Smooth tread	I-6
Cane and rice	R-2		
Industrial	R-3		
Garden tractor	G		

Ply Rating of Tires. The Tire and Rim Association and the Rubber Manufacturers Association have defined ply rating as follows: "The term 'ply rating' is used to identify a given type of tire with its maximum recommended load, when used in a special service. It is an index of tire strength and does not necessarily represent the number of cord plies in the tire." The ply rating for agricultural tires ranges from two to ten, depending upon the type of service. Small, lightweight tractors require only two-ply tires, while large, heavy tractors carrying mounted equipment require eight- to ten-ply tires.

Tire Sizes. Tractor tire sizes are designated by the tire cross-sectional diameter and the rim diameter. The tire size for front tractor tires is given as 4.00-15, 5.00-16, 5.25-21, 6.50-16, 7.00-16, and many others. The SAE Technical Committee recommends that the sizes of rear tractor tires be as follows: sectional diameters are to range in consecutive numbers from 6 to 15 with no fractional sizes. The rim diameters recommended are 24, 26, 28, 30, 34, 38, and 42. Typical stampings on the tire for size are shown as 9-24, 11-28, 12-26, 12-38, and 15-30.

Inflation Pressures. The use of proper inflation pressures is an important factor in the satisfactory performance and maintenance of tractor and implement tires. The recommended pressures vary with the tire size, the number of plies, and the service load. The maximum recommended pressures in pounds for the front wheels of tractors are: two-ply, 20 to 28; four-ply, 24 to 56; six-ply, 32 to 60; and eight-ply, 40 to 80. The minimum

inflation pressure for the rear tires on tractors is 12 pounds. When a tractor tire runs in a furrow while plowing, the pressure for the rear tire in the furrow should be increased by 4 pounds. The maximum recommended pressures in pounds for implement tires are shown in Table 8-2.

TABLE 8-2. RECOMMENDED AIR PRESSURES FOR TIRES USED ON FARM IMPLEMENTS

Tire size	Air pressure, lb.			
All rim diameters	4 ply	6 ply	8 ply	10 ply
3.00	44			
3.50	40	48		
4.00	36	48		
5.00, 5.50	32	44		
6.00, 6.50, 7.00	28	40	56	
7.50, 8.25	24	36	48	
9.00	20	32	44	56
11.25		28	36	44
12.75		24	32	

SOURCE: Firestone Tire & Rubber Company.

Agricultural tractor and implement tires are designed for a maximum speed of 20 m.p.h. Tires used on farm trailers should be of the automotive or truck type, which are designed for high speeds.

Rims for Tractor and Implement Tires. Rims now in use are usually of the drop-center type with a shallow or deep well. The trend is toward the use of wide-base rims with a shallow drop center (Fig. 8-3). The wide-

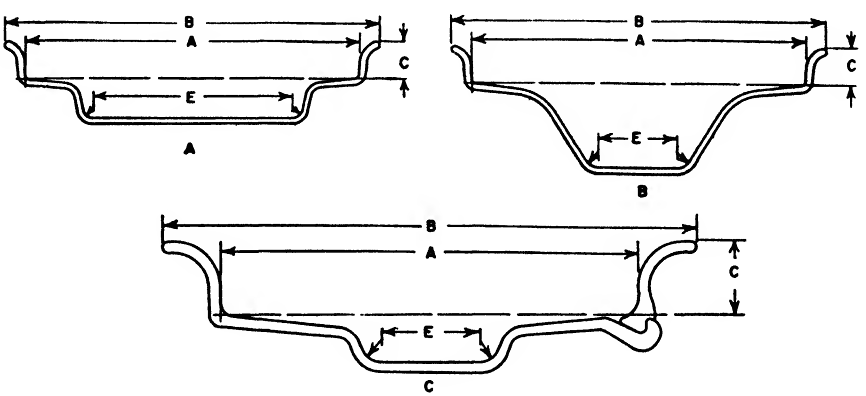

Fig. 8-3. Types of wide-base rims for tires: *A*, wide-base drop-center with shallow well; *B*, wide-base drop-center with deep well; *C*, wide-base semi-drop-center with split side ring.

base rim on a trailing implement allows for better lateral stability and provides a better shaped tire section to carry loads. A cross section of a wide-base semi-drop-center rim is shown in Fig. 8-3. There is a removable split side ring, which makes it easier to remove and mount heavy tires. The effect of rim width on tire performance is shown in Fig. 8-4.

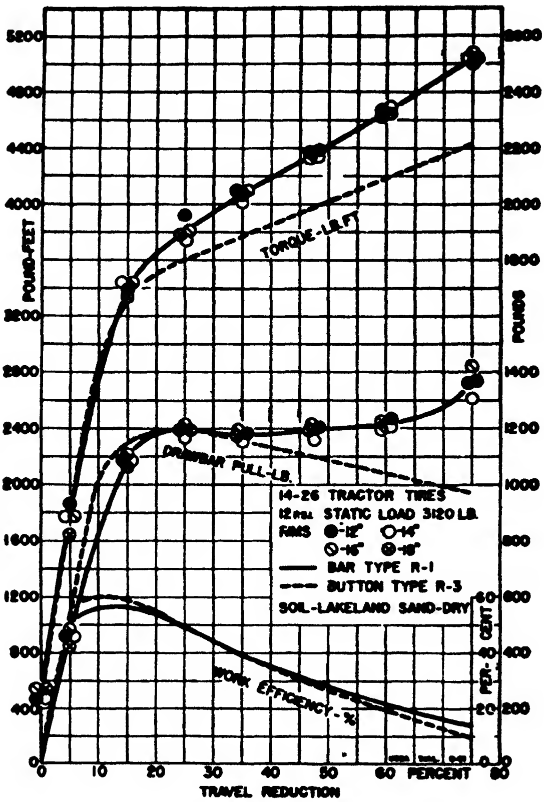

Fig. 8-4. The effect of rim width on tire performance is shown by the travel reduction, torque input, drawbar pull, and work efficiency for 14- to 26-inch six-ply, bar-type (R-1) tires mounted on 12-, 14-, 16-, and 18-inch rims and operated on dry sand at 12 pounds per square inch inflation and 3,120 pounds static load. Dynamic load was equal to static load plus 0.2 of 1 per cent of drawbar pull. Broken-line curves for button-type (R-3). (*U.S. Department of Agriculture, Tillage Machinery Laboratory.*)

Life of Agricultural Pneumatic Tires. There are many factors that affect the life of tires used on tractors and implements, such as (1) type of use, (2) type of farming and crop, (3) abrasive wear, (4) cuts and chipping, (5) punctures and blowouts, (6) exposure to weather, (7) improper inflation, (8) annual use, and (9) general care.

The bar graph in Fig. 8-5 shows the average life of front and rear tractor tires for various sections of the United States. The difference in the life of tractor tires in the different areas is greatly influenced by many of the factors enumerated above. High speeds, overloads, and underinflation will increase tire temperatures, damage the tire, and shorten its service life.

Traction of Tires. In the foregoing discussion it was shown that traction tires had treads designed to bite into the soil to give traction. Numerous

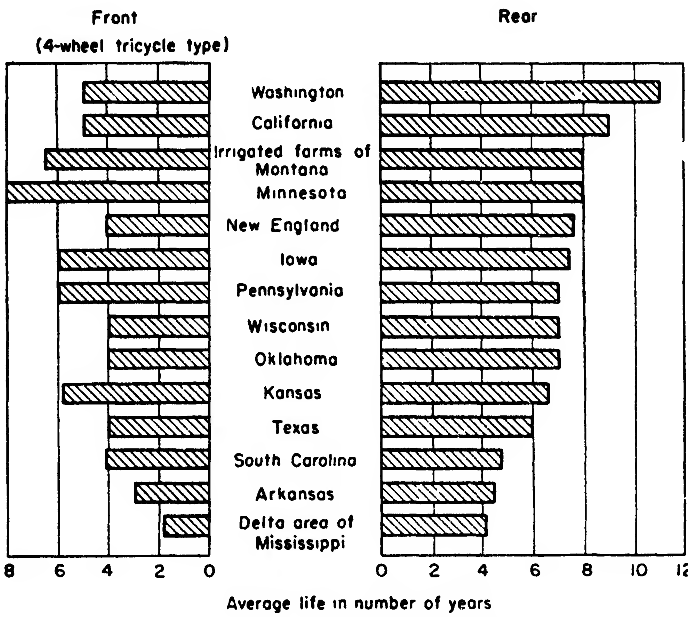

Fig. 8-5. Bar graph showing life of tractor tires in the various sections of the United States.

tests have been conducted to determine the effect of various surface conditions on tire traction. The traction efficiency for a tractor equipped with pneumatic tires is expressed as the ratio of the drawbar horsepower to the engine horsepower. This is true regardless of type of wheel equipment or tread.

Traction of the rear wheels on tractors is increased by adding weights to them. This is done either by attaching weights to the outside of the wheels or by filling the inner tube with liquid. If water is used in the tube, an antifreeze solution should be used where freezing conditions occur. The type of tread also is important in giving traction under different conditions (Fig. 8-6).

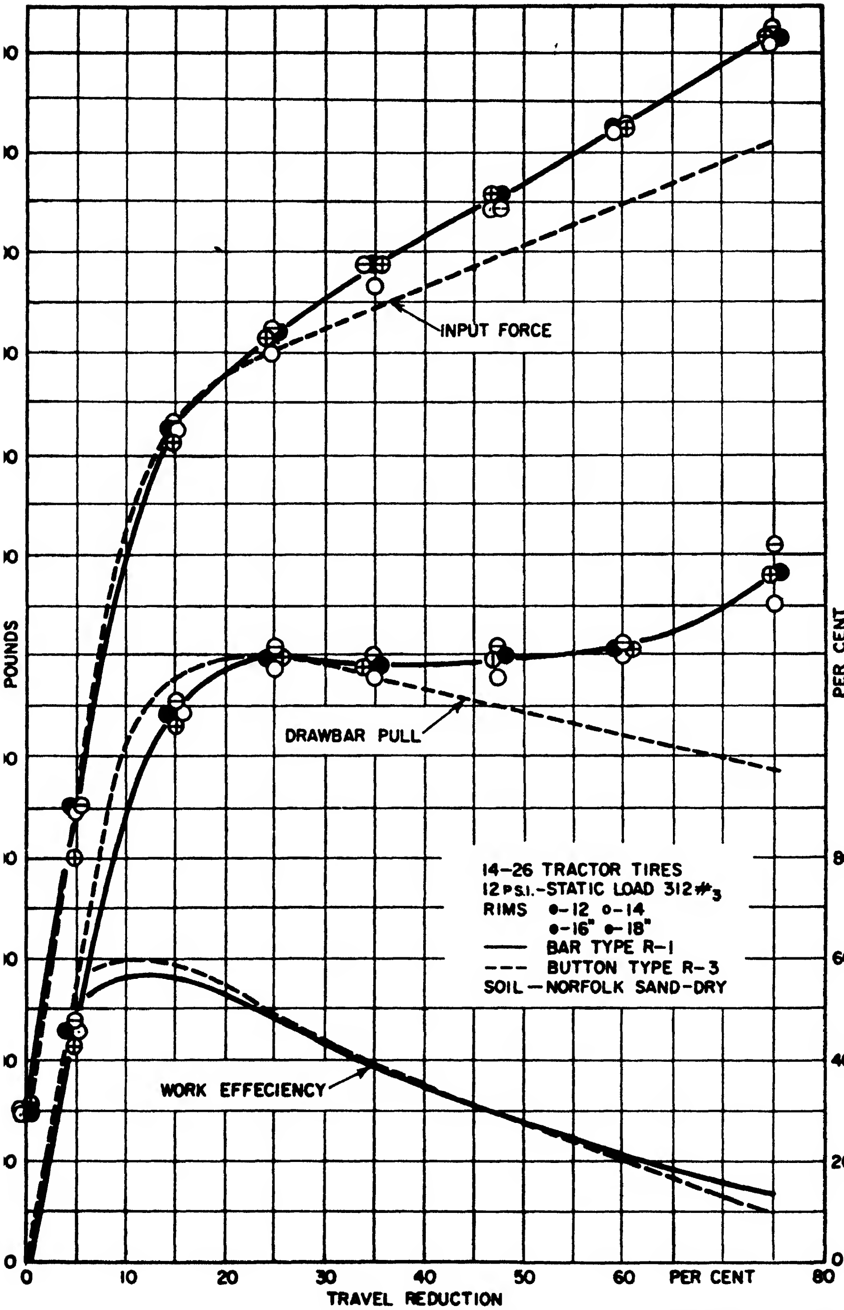

Fig. 8-6. Influence of type of tire tread on traction. (*U.S. Department of Agriculture, Tillage Machinery Laboratory.*)

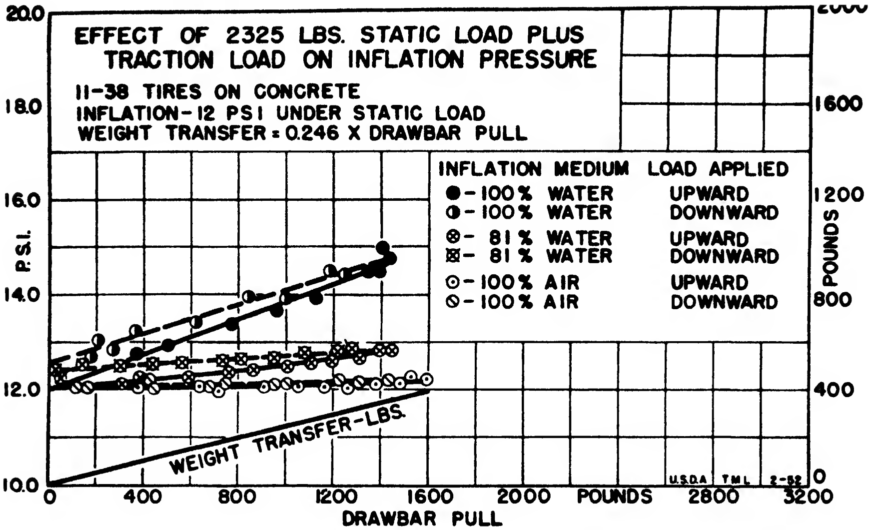

Fig. 8-7. Chart showing the increase in inflation pressure for tires filled with air, 81 per cent water, and 100 per cent water when the static load was varied from zero to 3,700 pounds. The initial inflation was 12 pounds per square inch with the tire on concrete and static load of 2,325 pounds. (*U.S. Department of Agriculture, Tillage Machinery Laboratory.*)

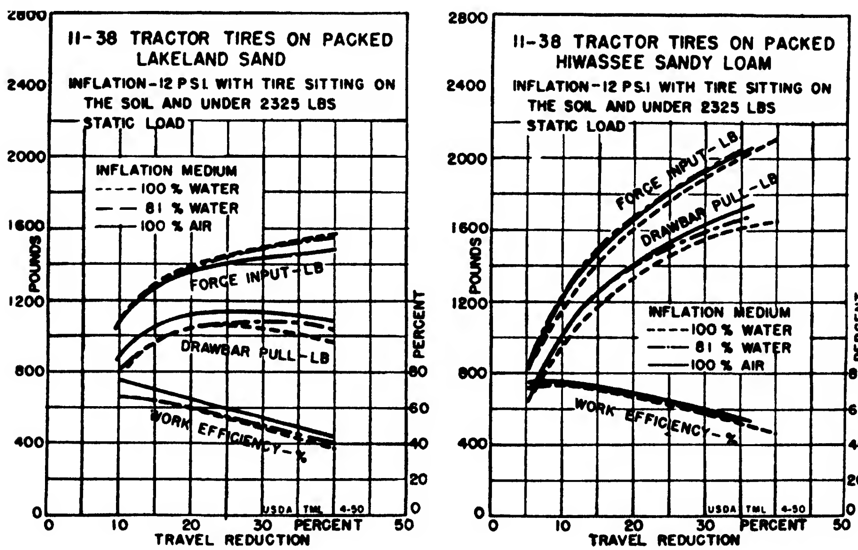

Fig. 8-8. Charts showing the effects of three kinds of ballast on the performance of tractor tires in packed Lakeland sand and Hiwassee sandy-loam soils. The inflation pressure was measured at the tire valve. (*U.S. Department of Agriculture, Tillage Machinery Laboratory.*)

Effect of Weighting Tires. Reed et al. state that "the effectiveness of tractor tires is markedly affected by the effective pressure at the bottom of the tire while under load. Higher pressures, whether caused by air or liquid, reduce the tire's effectiveness in loose sandy soils, but increase effectiveness on concrete and extremely firm soils." The performance of tires with three types of weights is shown in Table 8-3 and in Figs. 8-7 and 8-8.

TABLE 8-3. PERFORMANCE OF THREE TIRES IN TWO SOILS AT SELECTED LOADS

Type inflation	Soil type	Drawbar pull, lb.	Rolling resistance, lb.	Travel reduction	Work efficiency
Air	Sand	1,000	210	13.4	71.8
81% water	Sand	1,000	320	16.3	63.2
100% water	Sand	1,000	325	16.5	62.9
Air	Loam	1,400	240	19.2	69.1
81% water	Loam	1,400	275	20.2	66.7
100% water	Loam	1,400	320	23.6	62.0

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QUESTIONS AND PROBLEMS

1. Enumerate and discuss the advantages and disadvantages of pneumatic tires on farm equipment.
2. Explain the differences in traction and free-rolling tires and the agricultural tire code system.
3. Discuss the various factors that affect the life of agricultural pneumatic tires.
4. Discuss the various factors that affect the traction of tires.

TILLAGE HISTORY AND REQUIREMENTS

9

Tillage is the preparation of the soil for planting and the process of keeping it loose and free from weeds during the growth of crops. The primary objectives and fundamental purposes of tillage are divided into three phases: (1) to prepare a suitable seedbed, (2) to destroy competitive weeds, and (3) to improve the physical condition of the soil. Figure 9-1 shows that there were approximately 478 million acres of land tilled in the United States. This amounts to 24.9 per cent of the land area.

The basic tillage operation is the breaking of the soil in the preparation of a suitable seedbed. The breaking and loosening of the soil is the oldest phase of tillage as it includes the various types of plows. Prehistorically, it is assumed that man used crude tools of wood or other material with which he could loosen the soil. Perhaps a broken branch of a tree was the first tillage tool available to man. Later he learned to use fire or stone hand tools to fashion a soil-stirring tool from a fork of a tree by burning or hacking off one branch, leaving the longer one for the beam and the trunk part for a handle. Still later, he was able to use animal power to pull the plow.

History of the Plow. Recorded history in the form of hieroglyphs and cuneiform characters shows that the ancients had a type of plow thousands of years B.C. It is recorded that about 900 B.C. Elisha was found "plowing with twelve yoke of oxen before him."[1] Figure 9-2 shows a

[1] Kings xix:19.

farmer in eastern Turkey plowing with five yoke of oxen. The wooden plow with a metal share has been used for many centuries, and millions of wooden plows are still in use today. The parts of the wooden plow shown in Fig. 9-3 were held together entirely by animal-skin thongs. There were no nails, bolts, or haywire available to this man, so he used what he could find.

The Roman plow, which was improved by the Dutch, was imported into England about 1730. The Essex plow of about 1756 had an iron

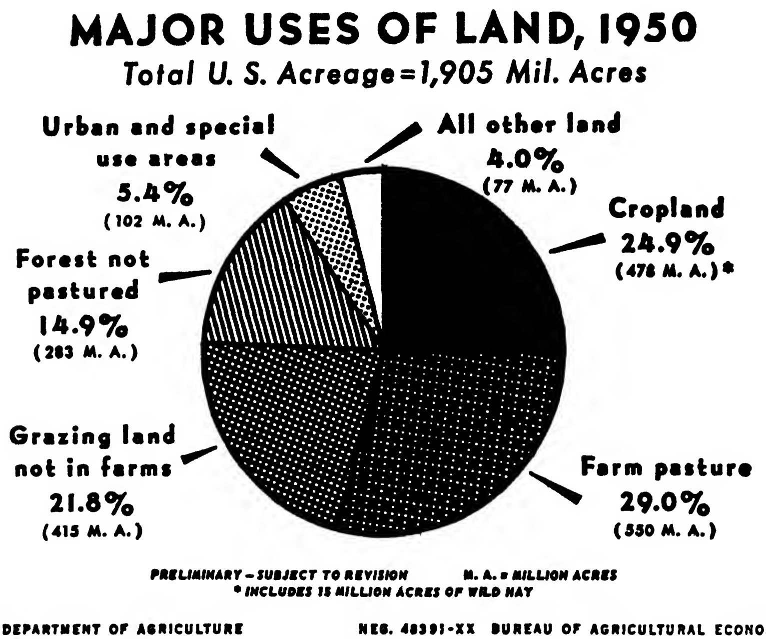

Fig. 9-1. Chart showing the major land uses in the United States.

moldboard. The Norfolk wheel plow of 1721 had a cast-iron share and an iron rounded moldboard. A curved moldboard made its appearance in 1760 on the Suffolk swing plow. The Rotherham plow was improved by James Small, who wrote a book on plow design in 1784. The close of the eighteenth century saw the change in England from the wooden plow to the iron plow.

In America, Thomas Jefferson and Daniel Webster were among the first to advance improvements of the plow. Charles Newbold of Burlington, New Jersey, secured the first patent on a cast-iron plow in 1797. Farmers rejected this iron plow because they thought it poisoned the soil. Jethro Wood developed a moldboard in 1814 of such curvature as to turn the soil in even furrows. The first steel plow was made from three sec-

tions of an old handsaw by John Lane about 1833. He also secured in 1868 a patent for soft-center steel, which is used at the present time in making moldboards for plows. In 1837, John Deere at Grand Detour, Illinois, made a steel plow (share and moldboard in one piece) from an old sawmill saw. Ten years later he established a factory at Moline, Illinois.

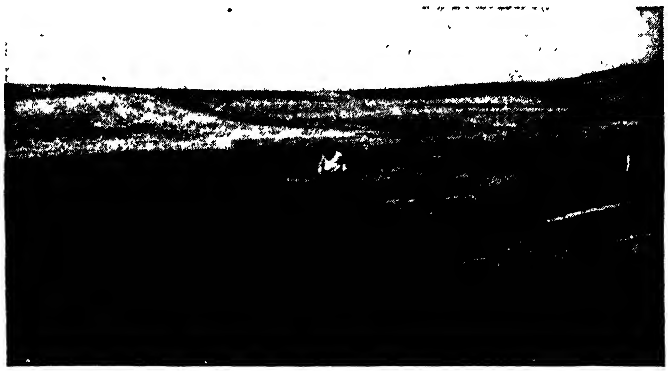

Fig. 9-2. Farmer in eastern Turkey plowing with wooden plow and five yoke of oxen.

Fig. 9-3. Parts of a wooden plow held together by animal-skin thongs.

James Oliver was granted a patent in 1868 for hardening cast iron which was known as chilled iron.

In 1856, M. Furley patented a single-bottom sulky or wheel plow which permitted the operator to ride. In 1864, F. S. Davenport patented a riding two-bottom horse-drawn gang plow. Three- and four-bottom gang plows often required ten to twelve horses to pull them.

The large ten- to fifteen-bottom plows were pulled by steam tractors in the 1890s and by the large, slow, cumbersome gasoline-engine tractors

from about 1900 to 1910. The early two- to five-bottom trailing-tractor plows were equipped with hand-lever lifts. In the early twenties, mechanical power lifts were developed. They were used until the hydraulic lift was introduced in the forties. The integral-tractor-mounted unit assembly and unit-lifted plow were developed in the early forties by Ferguson. This type of plow is now becoming popular on small and average-sized farms.

The disk plow was probably developed about 1890. Models were listed in implement catalogues by 1895. One of the earliest patents for a disk plow was secured by M. A. and I. M. Cravath, Bloomington, Illinois. J. K. Underwood, D. H. Lane, and M. T. Hancock made improvements on the disk plow and made it practical. Since 1900, the development of the disk plow has followed trends similar to that of the moldboard plow.

Influence of the Plow on Man. When man grasped a crooked stick and began to till the soil, he took his first step toward civilization. With each phase in the development of the plow, there has been a corresponding advance in civilization. A study of the history of mankind shows that it is possible to have culture without techniques, but there is no viable culture without the plow. In the beginning, one man, even though he gave all his time and energy to the task, could till only a small acreage. Later, animal power was applied and the acreage per man was increased. Now, with the large amount of mechanical power available, the acreage per man has been very materially increased. Thus, man can now produce more foodstuff than is necessary for his own sustenance and can furnish food to many who are working at other tasks. Hence, we can say that the plow is the foundation of civilization. In the production of all kinds of crops and in the preparation of a seedbed for them, the plow is the first tool used, and it is thus the basic tool of the farm. With the plow the ground is broken and pulverized into small particles; trash on the surface may be left on the surface or completely covered. One not familiar with the nature of the soil; the influence of water, air, and temperature upon its physical condition; and the action of the plow upon it may think that the plow is a very simple tool, requiring very little adjustment and practically no care at all. But those who are familiar with soil conditions and the plow adjustments necessary to obtain the best results know that the plow is the most important and complete tool on the farm, requiring the consideration of more factors for proper adjustment than does a gas engine.

Requirements of Tillage. A thoughtful analysis of the objects of tillage given in the following paragraph shows that a number of definite benefits are obtained by good plowing. The whole premise of high-yield crop production is based on the stirring of the soil with some type of implement, usually a plow, to provide a well-pulverized seedbed. In low-rainfall

areas, such as Montana, the Dakotas, and the western edge of the Great Plains, many farmers stir the subsurface without turning under and burying the crop residue. This reduces wind erosion. Experiments have shown that in areas receiving an annual rainfall of 20 inches or more, plowing is necessary to maintain crop yields. Certain soil types, like the heavy clay, are not adaptable to plowless farming because of their texture. Under humid conditions, unless the crop residue is well buried, insects and plant diseases build up and reduce yields. A soil well pulverized by plowing will absorb rainfall and retain moisture for crops, while the unplowed soil will lose most of the rainfall by runoff. Pulverizing the soil aerates it and enhances the activity of microorganisms and bacteria, causing rapid oxidation and decay of crop residues. Stirring the soil is an aid to nitrification and the liberation of plant nutrients within the soil.

In the preparation of the seedbed, it is necessary to keep in mind some of the benefits to be derived from such an operation. With the plow we strive to accomplish the following results:

1. To create a deep seedbed physically, chemically, and biologically fitted to the growth of crops
2. To add humus and fertility to the soil by covering and burying crop residues and manures so they are incorporated in the soil
3. To prevent and destroy weeds or other unwanted vegetation
4. To leave the soil in such condition that air will circulate freely
5. To leave the soil in such condition as to retain moisture from rain
6. To destroy insects, as well as their eggs, larvae, and breeding places
7. To leave the surface in a condition to prevent erosion by winds

Organic and Stubble-mulch Tillage. Advocates of the plow method of soil tillage are not, at the present time, ready to discard the plow completely for the organic and stubble-mulch methods. The plow farmers do admit that the addition of organic matter to the soil is beneficial in many ways and that the soil is protected by certain amounts of vegetative mulch from water and wind erosion. The soil is protected when crop residue is left on the surface, but the highest yields are obtained when the residue is cut up and worked into the soil. However, the addition of large volumes of crop residue to certain soils appears to disturb the action of microorganisms and retard natural nitrification. Under some conditions, this can be counteracted by the addition of extra amounts of nitrogenous fertilizers. Research programs on methods of handling crop residues, under way in several states, should be carefully watched for proven recommendations.

Kinds of Tillage Equipment. Tillage equipment can be divided into two general classes, namely, (1) primary tillage equipment and (2) secondary tillage equipment.

Equipment that is used to break deeply and loosen the soil to prepare a suitable seedbed may be considered as primary tillage equipment. Included in this group are the various kinds and types of moldboard, disk, and chisel plows. Secondary tillage equipment includes harrows, pulverizers, cultivators, weeders, and special tools for surface tillage to conserve moisture and destroy weeds.

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PROBLEMS

1. Define tillage and give the purposes of tillage.
2. Trace the history of the development of plows.
3. Discuss the relationship of the plow to the progress of mankind.
4. Discuss the requirements of good tillage practices.
5. Discuss methods and effects of handling crop residues.
6. Classify types of tillage equipment.

PRIMARY TILLAGE EQUIPMENT

10

The equipment used by the farmer to break and loosen the soil for a depth of 6 to 36 inches is called *primary tillage equipment*. It includes the moldboard, disk, rotary, chisel, and subsoil plows.

MOLDBOARD PLOWS

The moldboard plow is adapted to the breaking of many types of soils and is well suited for turning under and covering crop residues.

The Moldboard Plow Bottom. The part of the plow that actually breaks the soil is called the *bottom* or *base* (Fig. 10-1). It is composed of those parts necessary for the rigid structure required to lift, turn, and invert the soil. The parts which form the moldboard plow bottom are the *share*, the *landside*, and the *moldboard*. These three parts are bolted to an irregular-shaped piece of metal called the *frog*. The *beam* can also be attached to the frog (Fig. 10-1).

When a bottom is used to turn the soil, it cuts a trench called a *furrow* (Fig. 10-2). The ribbon of soil cut, lifted, and thrown to the side is called the *furrow slice*. When plowing is started in the middle of a strip, a furrow is plowed across the field, then the tractor and plow are turned about, and on the return trip a furrow slice is lapped over the first slice. This leaves a slightly higher ridge than the second, third, and other slices. This raised ridge is called a *back furrow* (Fig. 10-2). When two strips of land are finished, the last furrows cut out leave a trench about twice the width of one bottom. This open trench is called a *dead furrow* (Fig. 10-2). The unbroken side of the furrow is called the *furrow wall* (Fig. 10-

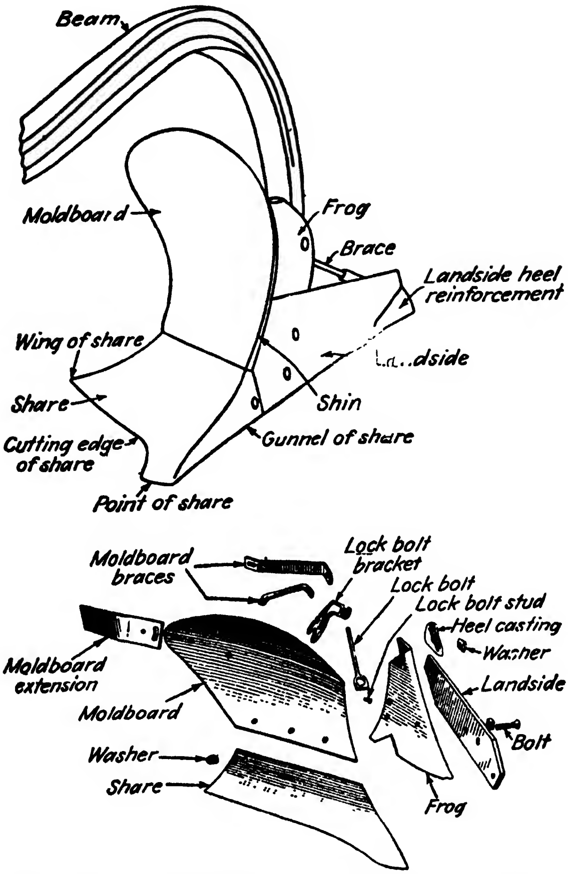


Fig. 10-1. Assembled and exploded view of moldboard plow bottom and parts.

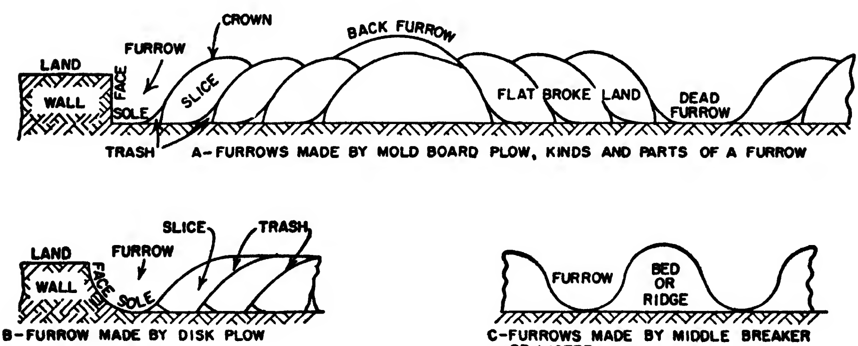


Fig. 10-2. Kinds of furrows made by different types of plows. (*Drawing by author.*)

2). When the land is broken by continuous lapping of furrows, the land is said to be *flat broken*. If the land is broken in alternate back furrows and dead furrows, it is called *bedded* or *listed* land.

The Moldboard. The moldboard is that part of the plow just back of the share. It receives the furrow slice from the share and turns it. When the action of the plow bottom upon the soil is considered, the moldboard is the most important part of the plow because it is upon the moldboard that the furrow slice is broken, crushed, and pulverized (Fig. 10-1). On some moldboards an extension is provided to turn the soil over more gradually and completely (Fig. 10-3). Different soils require different-shaped moldboards to give the same degree of pulverization. For this reason moldboards are divided into several classes, namely, *stubble, general-purpose, blackland, breaker,* and *high-speed* (Figs. 10-3 and 10-4). In classifying moldboards, it should be kept in mind that there are hundreds of shapes of each class. Such diversity of shapes has resulted in an attempt by manufacturers to make a plow that will do good work in all types of soils, but one that will work successfully everywhere is yet to be made. A special shape called the *blackland* bottom (Fig. 10-4) is used extensively in Texas and in other localities where the soil does not scour (leave the surface clean and polished) well.

The general-purpose moldboard is a combination of the sod and stubble types and can be used easily for sod or stubble land. It has less curvature than the stubble moldboard. Hence, it is called a *general-purpose plow.*

The stubble type of moldboard (Fig. 10-3) is broader and bent more abruptly along the top edge. This causes the furrow slice to be thrown over quickly, pulverizing it much better than the other types of molds. This type is best suited to work in soil that has been cultivated from year to year, called *stubble soil* because of the fact that the stubble of plants from the previous crop is still on the land. Unlike the sod plow, the furrow slices lap upon one another.

A breaker bottom is designed to work in sod land and in land that has remained idle for a number of years.

The high-speed bottom (Fig. 10-4) has slightly less curve to the upper section of the moldboard than does the general-purpose moldboard. It is designed to throw the furrow slice just far enough to lap upon the previous furrow slice.

Slat moldboards (Fig. 10-5) are often used where the soil is sticky and does not scour on solid moldboards.

Generally, there are three materials used in the manufacture of moldboards, namely, *soft-center steel, crucible steel,* and *chilled cast iron.* Soft-center-steel moldboards are the best to use under most conditions because the majority of soils will scour better on this type of material.

For the Middle West, the steel plow seems to give satisfaction in most cases. Because of their wear-resistant qualities owing to the hardness of the material of which they are made, chilled plows are better for sandy, gritty, and gravel soils. Chilled plows are adaptable to all parts of the

Fig. 10-3. Three commonly used types of moldboard plow bottoms: *top,* stubble; *middle,* general purpose; *bottom,* breaker. (*International Harvester Company.*)

Fig. 10-4. Three special types of moldboard plow bottoms: *top,* high-speed; *middle,* deep-tillage; *bottom,* blackland. (*International Harvester Company.*)

South, where there is much sandy land. Plastic-covered moldboards are now available.

The Share. The share of a moldboard plow (Fig. 10-1) provides the cutting edge. The principal parts of the share are the *point,* the *wing,* the *cutting edge,* and the *gunnel* (Fig. 10-1). The kinds of shares are the

regular with gunnel, two-piece, and *straight.* The latter two are designed so that, when they become worn and dull, it is more economical to replace them with new ones than to try to resharpen them (Fig. 10-6). Chilled-cast-iron shares can be resharpened by grinding.

Fig. 10-5. Slat-type moldboard plow bottom. (*J. I. Case Company.*)

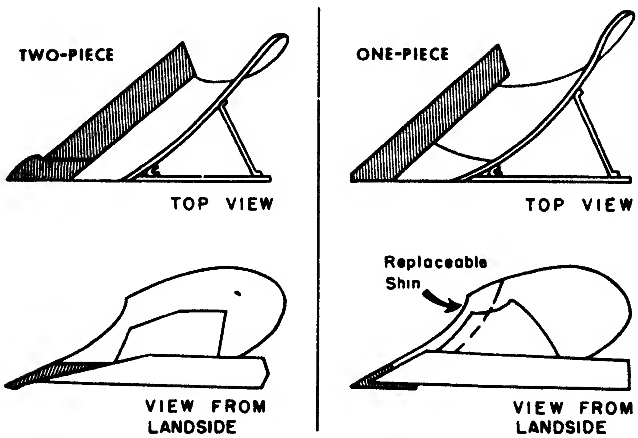


Fig. 10-6. The shaded areas show two types of simplified or replaceable plow shares: *left,* two-piece; *right,* one-piece. (*U.S. Dept. Agr. Farmers' Bul.* 2172, 1961.)

Figure 10-7 illustrates three degrees of suction: regular-suck, deep-suck, and double-deep-suck. The amount of suction is around 3/16, 5/16, and 3/8 inch, respectively.

Vertical or *down suction* is the bend downward of the point of the share to make the plow penetrate the soil to the proper depth when the plow is pulled forward. The amount of suction will vary from 1/8 to 3/16 inch depending on the style of the plow and the soil it was made to work in.

Horizontal or *land suction* is the amount the point of the share is bent out of line with the landside (Fig. 10-8). The object of this suction is to make the plow take the proper amount of furrow width.

Landside. The *landside* is that part of the plow bottom which slides along the face of the furrow wall. It helps to counteract the side pressure exerted by the furrow slice on the moldboard. It also helps to steady the plow while it is being operated. The *shin* (Fig. 10-1) is the cutting edge of the moldboard, just above the landside.

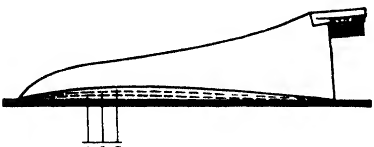


Fig. 10-7. Three degrees of share suction: 1, regular-suck: 3/16 inch for light soil easy to penetrate; 2, deep-suck: 5/16 inch for ordinary soil that is dry and hard; 3, double-deep-suck: 3/8 inch for stiff soils, gravel land, and other soils where penetration is difficult.

Size of the Plow. The *size* of a moldboard plow is its width in inches. This is determined by measuring the distance from the wing to the landside. The rule is held perpendicular to the landside. Tractor plow sizes are 10, 12, 14, 16, and 18 inches. Special brush plows may be as large as 18 and 20 inches.

Types of Tractor Moldboard Plows. In general, tractor moldboard plows may be grouped into three types: *trailing, semimounted,* and *integral-mounted.*

Trailing Moldboard Plows. The *trailing,* or *pull-type,* tractor plow is a complete unit in itself, supported by two or three wheels; when hitched to the drawbar of the tractor, it trails behind the tractor.

Regular Trailing Plows. Trailing moldboard plows are built in sizes ranging from one to five bottoms. The size of the bottoms may range from 12 to 18 inches, but the most common size is 14 inches.

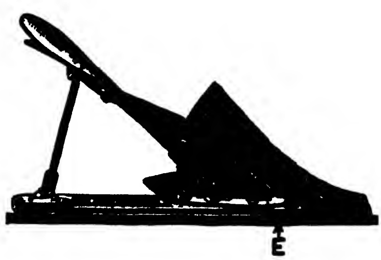


Fig. 10-8. Position of straightedge to measure the horizontal or land suction at *E.*

The two-, three-, four-, five-, and six-bottom moldboard plows can be obtained with hydraulic lifts (Fig. 10-9). The smaller sized trailing plows may have the rear furrow wheel either rigidly attached or arranged so that the wheel will castor, or a long landside may be substituted for the wheel. The larger plows can be adjusted with either hand levers or screw cranks. Generally, trailing plows are provided with A-frame-type hitches. Some trailing plows have an overhead curved beam of I-shaped steel, while others have a fabricated trussed standard-type beam, which, it is

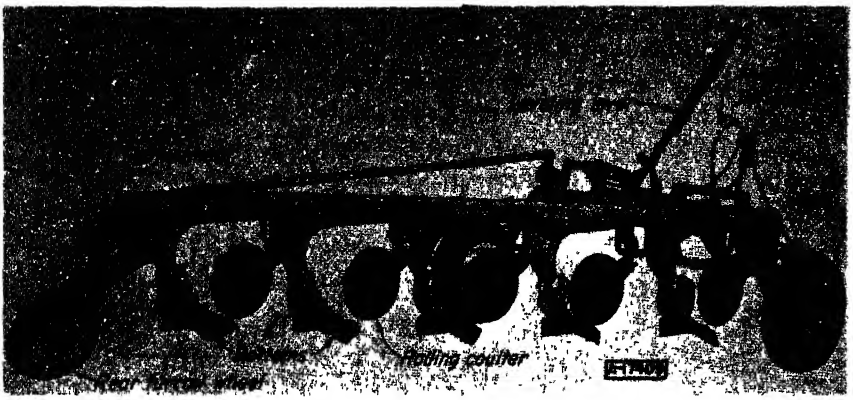


Fig. 10-9. Five-bottom trailing moldboard plow equipped with remote-control hydraulic cylinder lift. (*J. I. Case Company.*)

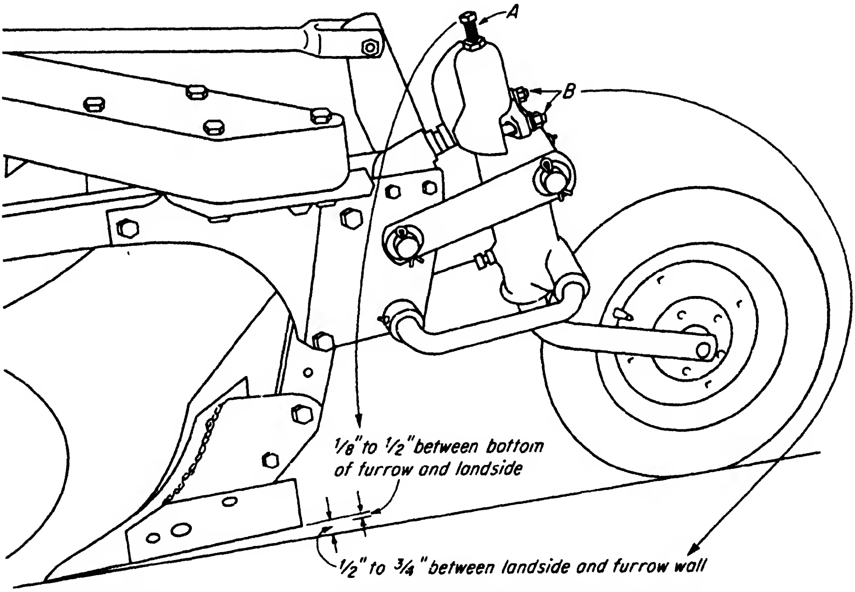


Fig. 10-10. Showing range of adjustment for vertical and horizontal suction on a trailing moldboard plow. (*J. I. Case Company.*)

claimed, gives a higher clearance. Most of the multiple-bottom plows are designed so that one bottom can be removed, thereby reducing the size. Wheels equipped with rubber tires are optional.

The heel of the landside on the rear bottom of trailing plows should be adjusted to run from ½ to ¾ inch above the furrow sole and out from the furrow wall (Fig. 10-10). The rear furrow wheel carries almost one-

third of the plow's weight and load. If a multiple-bottom plow is throwing unequal furrows and is difficult to adjust, it should be checked for sprung beams by measuring from share point to beam. Figure 10-11 shows a plow bottom equipped with a spring trip to clear obstacles.

Two-way Trailing Plows. This plow is named *two-way* because it has both right- and left-hand bottoms and, therefore, throws the furrow slices both to the right and to the left of the operator, as the plow is reversed

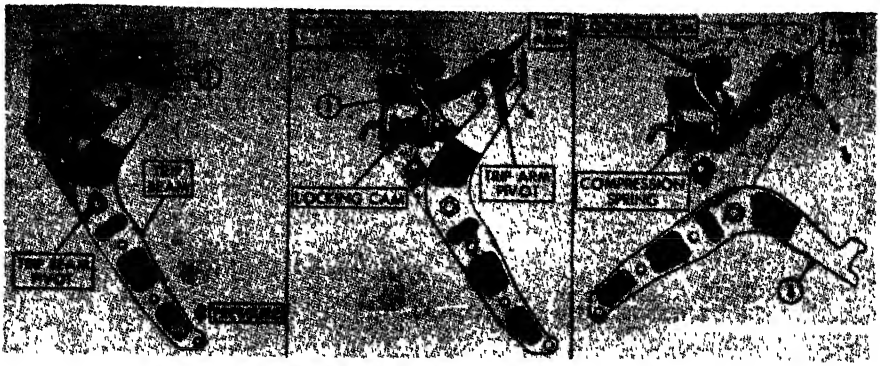


Fig. 10-11. Tripping cycle of a spring-trip plow beam. (*Deere & Co.*)

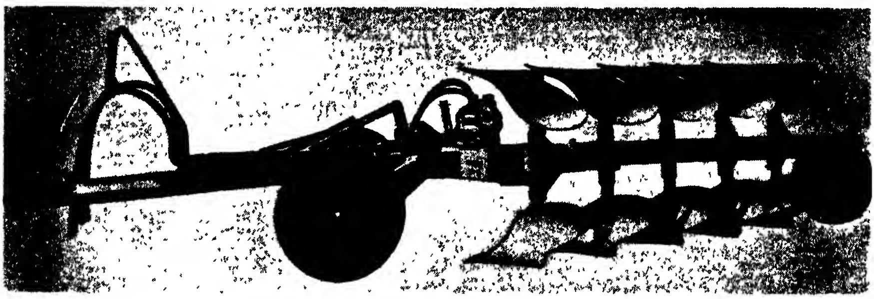


Fig. 10-12. Five-bottom trailing two-way moldboard plow equipped with hydraulic lift and reversible mechanism. (*Atlas Scraper & Engineering Co.*)

when the tractor is turned at the turn row. The furrow slices, therefore, are thrown in one direction in relation to the field (Fig. 10-12).

The two-way plow is used in plowing irrigated lands and where it is desirable to break the land without leaving a dead furrow, such as hillsides, terraced fields, and irregular-shaped fields.

Semimounted Moldboard Plows. This type of plow has the front end directly connected to and supported by the tractor (Fig. 10-13). The rear end of the plow is supported by a furrow and a land wheel. The raising and lowering of the rear part of the plow on the furrow wheel

may be either by a mechanical linkage or by a remote-controlled hydraulic cylinder. The front end of the plow is raised and lowered by the tractor hydraulic linkage system. Usually this type of plow is attached to the tractor by a quick-coupling mechanism.

Integral-mounted Moldboard Plows. This type of plow also is called a *direct-connected, tractor-mounted,* or *tractor-carried* plow.

Regular Mounted Plows. The integral-mounted plow is really a tractor attachment, as it depends upon the tractor for its power lift and the power of the tractor engine for its general operation. The entire weight of the plow is carried on the tractor when lifted (Fig. 10-14). The depth

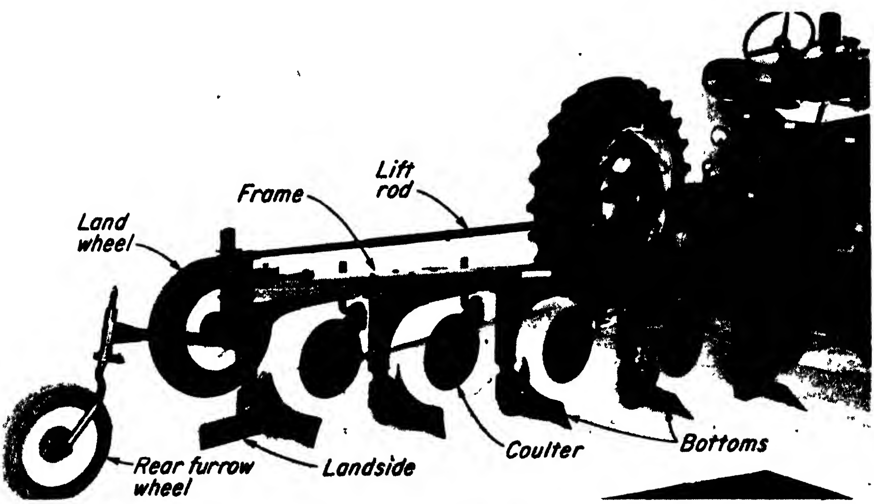


Fig. 10-13. Semimounted five-bottom moldboard plow. (*International Harvester Company.*)

of plowing is controlled in some cases hydraulically, in others by levers and gage wheels. The number of bottoms ranges from one to five, depending upon the size of the tractor. The smallest tractor of 8 to 10 drawbar horsepower may be equipped with a single 12-inch bottom. The medium-sized tractor carries two bottoms, while the large-sized tractor can carry up to five bottoms (Fig. 10-14).

The weight and length of the tractor ahead of the drive wheels determine the weight and length of the plow that can be mounted and lifted behind the drive wheels. In some cases extra weight must be added to the front of the tractor to counterbalance the plow and prevent interference with steering. One company offers an eight-bottom plow. It is attached to a large and heavy 200-horsepower four-wheel-drive tractor.

The integral-mounted plows are unit assemblies, and the unit is mounted and attached to the tractor by specially designed hookups for

quick attaching and detaching. The larger plows usually have a linkage-hitch arrangement for lifting and leveling the plow. All mounted plows are lifted by hydraulic lifts. As the plows are tractor attachments, no wheels are required except for a small landside wheel at the rear.

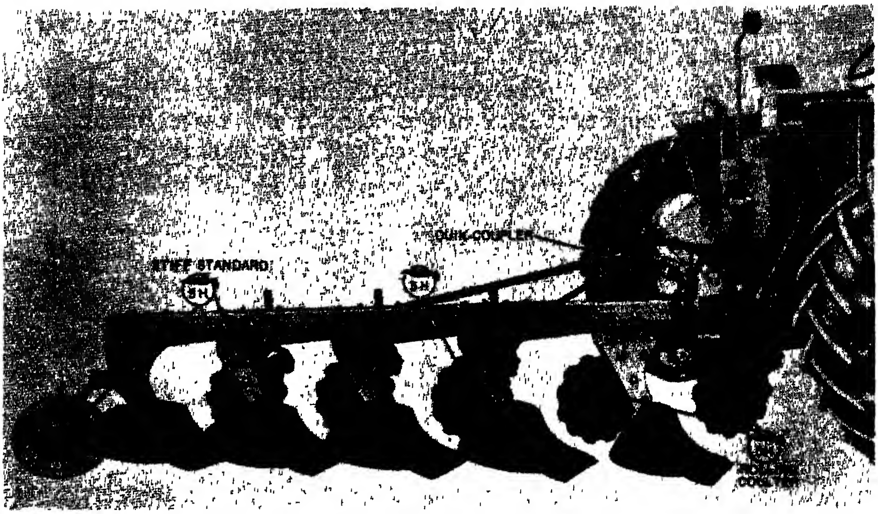


Fig. 10-14. Integral-mounted five-bottom moldboard plow with quick coupler and notched colters. (*Deere & Co.*)

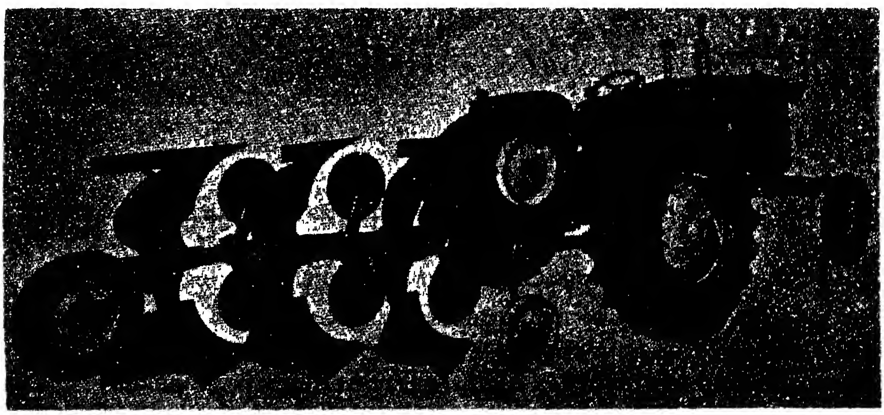


Fig. 10-15. Integral-mounted two-way moldboard plow. (*Allis-Chalmers Mfg. Co.*)

Two-way-mounted Moldboard Plows. The two-way-mounted plow performs the same functions as the trailing two-way plow. A different arrangement is provided to change from right- to left-hand bottoms. This is accomplished by rotating the unit 90 degrees for some plows and for others 180 degrees (Fig. 10-15). One company describes this change as

a vice versa action. The action may be either mechanically or hydraulically controlled.

Integral-mounted Middlebreakers. The middlebreaker is known by different names in different sections. In the South, it is often called a *middlebuster* or *bedder*, but where crops are planted in the furrow, it is called a *lister*. The bottom is really a right- and a left-hand moldboard plow joined together. In most cases the share or point is one piece with wings to fit against each moldboard. Shares may have the wings and the central point separated into three pieces that fit closely. The shapes of the moldboards range from the stubble to the blackland types (Fig. 10-16). In some areas for certain jobs sweeps are substituted for the moldboard bottoms (Fig. 10-16).

There are two types of mounted middlebreakers: the *rear-mounted* and the *front-mounted*. They are so called because of their position in relation to the rear wheels when mounted on the tractor (Figs. 10-17 and 10-18).

Fig. 10-16. Three types of middlebreaker bottoms: *top*, general purpose; *middle*, blackland; *bottom*, middlebreaker sweep. (*International Harvester Company.*)

Rear-mounted Middlebreaker. The *rear-mounted middlebreaker* is usually attached to a tool bar and is easily detached. In most makes, the removal of two bolts is all that is necessary. The beams also can be moved sidewise along the tool bar for different row spacings. When plowing in soil where there may be hidden obstructions, such as roots or stones, a spring trip (Fig. 10-11) or a friction release can be obtained. The depth of plowing, which can be adjusted by levers, is controlled and held uniform by gage wheels. Units with five or six bottoms are available.

Front-mounted Middlebreaker. The *front-mounted middlebreaker* may be equipped to operate with two or five bottoms but not more than five in front of the tractor drive wheels. Some units have four bottoms in front and one in the rear of the tractor drive wheels, thus making a five-bottom combination (Fig. 10-18). When mounted in front of the tractor drive wheels, the unit is often referred to as a *central-mounted* or *suspended* tool. The unit also may be called a *push-type middlebreaker* because the bottoms are pushed forward ahead of the tractor drive wheels (Fig. 10-18).

The front-mounted middlebreaker is equipped with gage wheels,

power lifts, and means to adjust for different row spacings (Fig. 10-18). Three- and five-bottom middlebreakers usually have the odd bottom mounted to the rear of the tractor (Fig. 10-19).

The front-mounted arrangement makes it possible to use tractors equipped with pneumatic tires in the field when the surface is wet enough to cause excessive wheel slippage. This is because the tractor drive

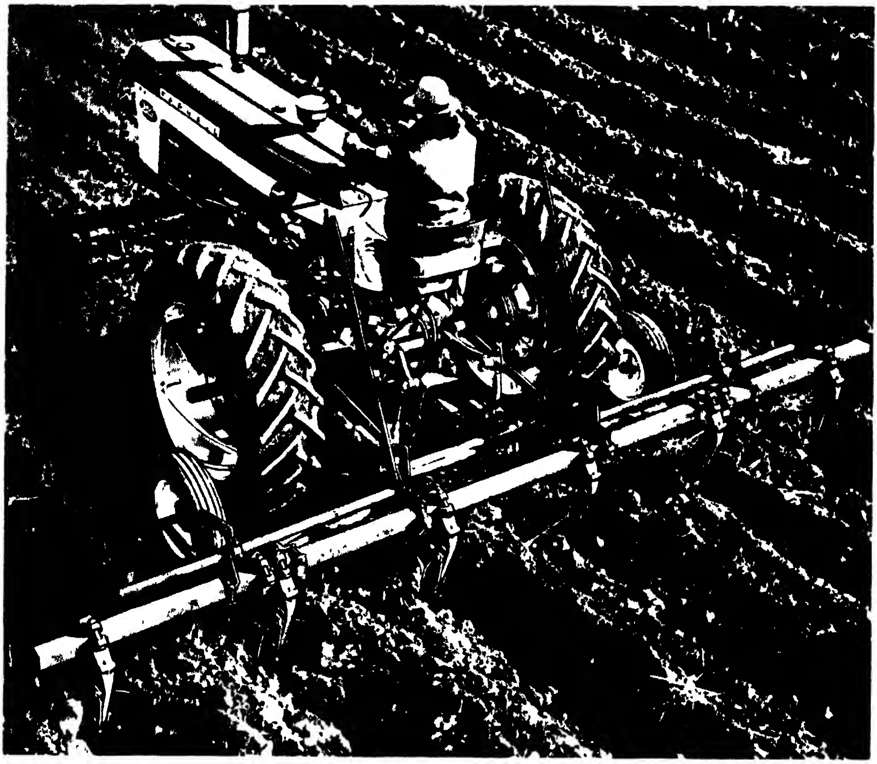


Fig. 10-17. Integral-rear-mounted six-bottom middlebreaker or bedder-lister. (*International Harvester Company.*)

wheels operate in the furrows made by the middlebreaker bottoms which are mounted in front of the wheels. The surface may be wet, but the tractor wheels operate on comparatively dry soil. Land can be bedded and rebedded and beds reshaped. When the land has been bedded or listed for some time and rains and winds have partially filled the furrows with soil, it is desirable to clean out the furrows with the middlebreaker bottom, throwing some soil up on the edges of the bed and thereby reshaping it. This operation is called *hipping* by farmers of the Mississippi Delta area.

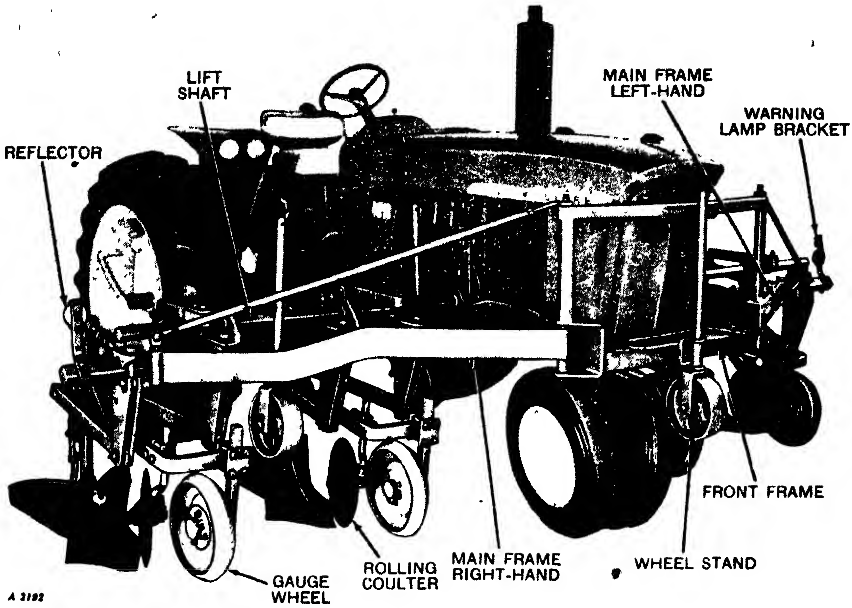


Fig. 10-18. Integral-front-mounted five-bottom bedder with rolling colters. Figure 10-19 shows the rear bottom. (*Deere & Co.*)

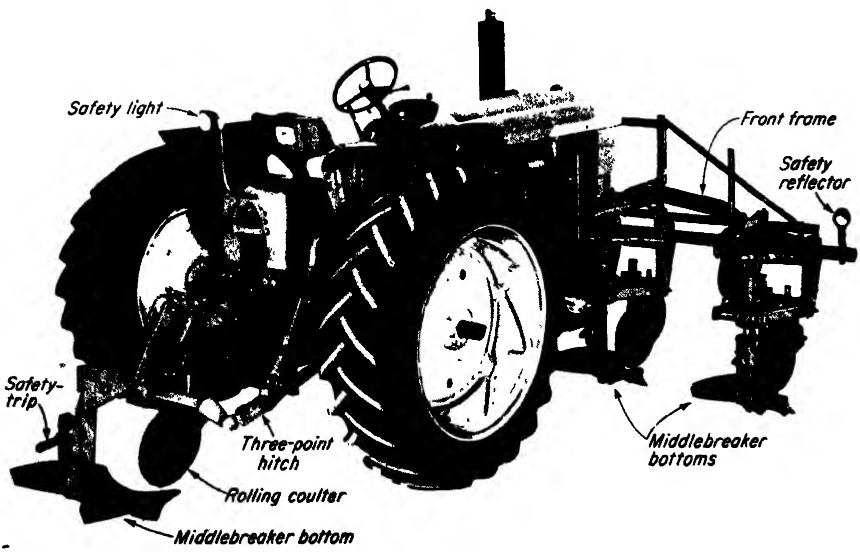


Fig. 10-19. Rear view of five-bottom bedder showing the rear bottom. (*Deere & Co.*)

There are several attachments for middlebreaker bottoms, such as gage wheels, rolling colters, root cutters, and planting equipment.

Design of Moldboard Plows. To design a plow which will perform satisfactorily under all soil conditions is a problem that has never been entirely solved, yet more work has been done on perfecting the plow bottom than on any other agricultural implement. Upon its performance depends the quality of the seedbed the farmer can prepare, which in turn will influence the germination of the seed, the growth of the plant, and the yield that will be obtained in the end. Therefore, the farmer should strive to do a good job of plowing. Good plowing consists of turning and setting the soil into even, clean furrows of roundish conformation.

The main points to consider are the following:

1. The top of the furrow may be slightly ridged.
2. The soil must be pulverized thoroughly from the top to the bottom of the furrow.
3. Each furrow must be perfectly straight from end to end on level land.
4. All back furrows must be slightly raised, and all trash completely covered.
5. The outline of the furrows must be in a point without break or depression.
6. All trash must be buried completely in the lower right-hand corner of the furrow.
7. Furrows must be thoroughly uniform.
8. The depth of all the furrows must be the same, continuing in uniform depth.
9. The dead furrows must be free of all trash.
10. Unbroken strips must not be left between furrows in contour plowing.

These are the standards to consider when plows are used and, of course, do not apply where it is desirable to leave the crop residue on the soil surface. The main thing to consider in plowing is that the land be completely broken and that the soil be thoroughly pulverized (Fig. 10-20).

The whole bottom is essential for good plowing, the share cutting and slightly lifting the furrow slice, the landside controlling and steadying the plow, while the moldboard completes the lifting, pulverizing, and inverting of the furrow slice. It is upon the moldboard that the main part of successful plowing depends. The curvature and length of the moldboard determine the degree of pulverization given the furrow slice.

Forces That Act on the Plow. Lindgren and Zimmerman[1] analyze the many forces that act upon the plow bottom as follows:

[1] Lindgren and Zimmerman, *Amer. Soc. Agr. Engin. Trans.*, 15:150, 1921.

First, the principal vertical forces: (*a*) those that are due to the weight of the plow, (*b*) those that are due to the downward pressure exerted during the lifting of the soil, (*c*) the lifting component due to the hitch being above the point of resistance, and (*d*) that force developed when the plow is dull and worn, which has an upward component, the result of the sloping undersurface of the share.

Second, the principal horizontal cross-furrow forces: (*a*) the cross component caused by the friction of the soil on the moldboard, (*b*) the cross component caused by transferring the soil sidewise the width of the furrow, (*c*) the cross component due to cutting and wedging of the sloping share edge in operation, (*d*) the component of the line of draft, and (*e*) such cross component as may result from the rear-furrow-wheel reactions in multiple outfits, where used.

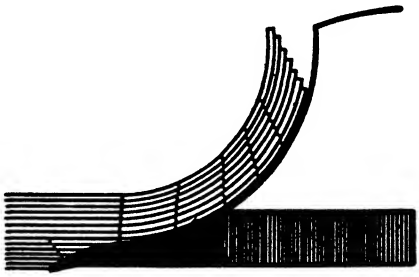


Fig. 10-20. Diagram showing the pulverizing or breaking of the furrow slice as it travels over the moldboard. Shorter and deeper curves cause more and finer pulverizing. The longer and shallower curves cause less and coarser pulverizing. (*Allis-Chalmers Mfg. Co.*)

Third, the principal longitudinal forces acting lengthwise of the furrow: (*a*) the soil resistance to cutting; (*b*) the friction between the furrow wall and the landside; (*c*) the friction due to the weight and pressure upon the bottom of the plow, according to the setting or condition of the cutting wedge; (*d*) the component of the friction of the earth sliding over the moldboard. For equilibrium we have the sum of the draft produced by the motive power.

Thus it can be seen that the moldboard, which is a modified warped surface, as analyzed by White,[2] will have a great deal to do with the proper functioning of the plow, depending upon its width, curvature, and length. Moldboards which have a greater curvature, being bluffer, will naturally give a better pulverizing action upon the furrow slice because of their pinching, crushing action (Fig. 10-20).

Clyde[3] explains and illustrates the relative size of the forces acting on moldboard plows by the length of arrows as shown in Fig. 10-21*A* and *B*. The soil resistance on the share and moldboard is shown by the line *RH*. The position and angle of *RH* will vary with the condition of the

[2] E. A. White, *Jour. Agr. Res.*, 12(4):149–182, 1918.

[3] A. W. Clyde, Mechanics of Farm Machinery, *Farm Impl. News*, Jan. 6 to Mar. 16, 1944; Force Measurement Applied to Tillage Tools, *Amer. Soc. Agr. Engin. Trans.*, 4:153, 1961.

soil. At any point on *RH*, the two unequal forces, *L* and *S*, can be substituted (Fig. 10-21*B*). *RH* makes an angle of 13½ degrees with the direction of travel, the side force S being 24 per cent of *L*. If the soil were perfectly uniform, theoretically the plow could be pulled with a force equal but opposite to *RH* and no side support would be needed.

If the pull is straight ahead as shown in Fig. 10-21*B*, the plow will need side support from the furrow wall. This support causes frictional drag,

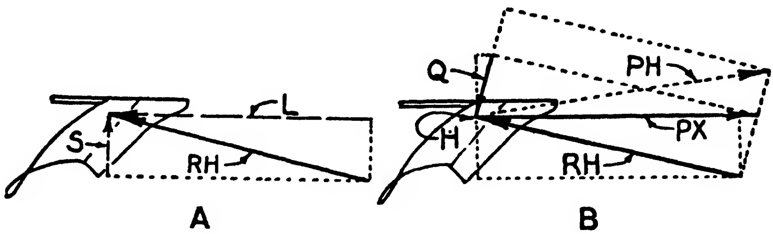


Fig. 10-21. Diagrams showing horizontal forces that act on a moldboard plow and their resultant. (*A. W. Clyde, University of Pennsylvania.*)

which is shown by the angle of *Q*. For side balance, the side component of *Q* must equal *S*, the side component of the soil force acting to the left. If a parallel-sided figure is constructed on *RH* and *Q*, the single force *PX* will balance them. *PX* is a little more than *L* in Fig. 10-21*A*, because *PX* also overcomes the landside friction. Note that *PX* passes through *H*, the junction of *RH* and *Q*. The point *H* is commonly called the *center of resistance* of a plow bottom. If the pull is at an angle *PH*, it must go through *H*. This angled pull forces the plow harder against the furrow wall. In Fig. 10-21*B*, the angle of *PH* is such that its side component is nearly 80 per cent of S, and it is in addition to S.

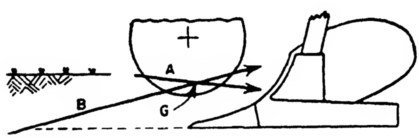


Fig. 10-22. The line *A* represents upward forces for fairly easy plowing, while line *B* is for hard plowing. The point *G* is the average soil resistance which is slightly below the soil surface. (*A. W. Clyde, University of Pennsylvania.*)

As a well-shaped share lifts the furrow slice, the vertical forces appear to be downward. A rolling colter operating above the share point must be forced into the soil, and therefore the forces are upward. The degree of the upward forces exerted by the colter is influenced by the hardness of the soil. This is shown in Fig. 10-22.

Center of Resistance or Center of Load of a Plow Bottom. The above discussion shows that a point where all the horizontal and vertical forces meet is considered to be the *center of resistance* or *load* (Fig. 10-23). It cannot always be determined just exactly where this point will be on a

plow bottom, but it will usually come within the range of the following dimensions for a 14-inch bottom: vertical forces will be in equilibrium 2 to 2½ inches up from the floor; the horizontal forces 2 to 3 inches to the right of the shin; the longitudinal forces 12 to 15 inches back from the point of the share. Briefly, we can say that the center of resistance of any moldboard plow bottom will be on the surface about where the share and moldboard intersect and to the right of the shin (Fig. 10-23). If two

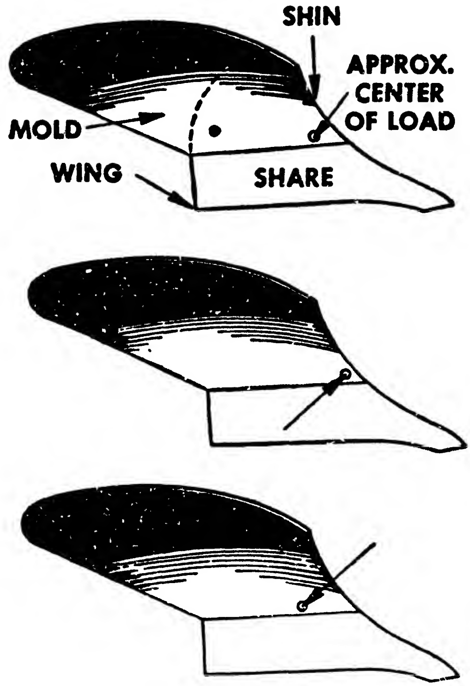


Fig. 10-23. The circles on the bottoms show the approximate point where the various forces acting upon the plow are in equilibrium for different soil types: *top*, average soils; *middle*, light soils; *bottom*, tough soils. (*International Harvester Company.*)

or more bottoms are used, the center of resistance will be the average of all the centers. The style of bottom as to shape, type of share, and moldboard will influence the point where all the various forces acting on the bottom will be in equilibrium.

Influence of Friction on Design. After all the above principles are taken into consideration, they resolve themselves into one general principle of plow design that must be considered in every type of plow, whether it is stubble, general-purpose, or sod. That principle is that friction will be the greatest at the point of the share and gradually decrease

backward to the end of the moldboard. This can be seen readily on any plow bottom after considerable use. The greatest amount of wear is found to be at the point; this gradually decreases backward to the tip of the wing of the moldboard. This is why the stubble moldboard, which has a greater amount of curvature, gives better pulverization to the furrow slice. It is also seen that this type of moldboard will pick up the soil quicker and turn it over harder than any other type. That makes this type of plow more adaptable to plowing the loams and the sandy-loam soils. The general-purpose moldboard has a smaller amount of curvature than the stubble; it is in this class that the blackland type of plow falls, because its curvature is not so pronounced as that of the stubble moldboard.

Influence of Speed on Design. In the last few years, there has been much agitation regarding the designing of plows for high speeds. It is not so difficult to design a plow for high speeds as it is to obtain pulverization. The bottom designed for high speeds must have gradual curves, which approach closely those of the sod type of plow. It can be seen readily that it is not necessary to have the moldboard as wide in this case in order to lift and invert the furrow slice. The higher velocity will carry the soil up over the moldboard, throwing it farther to the side. Much difficulty is likely to result from plows for high speed which must incorporate a plow bottom of long slopes. They may scour well while going at a high rate of speed, but when the speed drops to 2 or 3 m.p.h., will they continue to scour at this speed? Will they do the same type of work as at the higher speed?

Type of Soil. Another important factor influencing plow design is the type of soil. In fact, if it were not for the soil factors, designing of plows would be a comparatively simple matter. Brown[4] says: "The types of soil, from sands, through the loams to the clays, are affected differently by the same plow bottom, and since the prime object of plowing is to put the soil in the proper condition of tilth for the successful growing of crops, it follows that there must be a variety of plow shapes."

Methods Used to Aid Scouring of Moldboard Plows. A plow is said to *scour* when the soil sheds clean from the moldboard and leaves a polished surface. Plow designers have used various materials in an effort to obtain good scouring qualities. Materials such as steel, iron, glass, aluminum, plaster of Paris, and hog hide have been used. It was found that plaster of Paris and hog hide gave better results than steel, iron, glass, and other materials. Other attempts have been made with special types of bottoms having holes through which water could flow and keep the surface of the moldboard wet. Fairly good results have been obtained by heating the moldboard by the use of the tractor exhaust flowing into an enclosed

[4] Theo Brown, *Amer. Soc. Agr. Engin. Trans.*, 19:24, 1925.

space underneath the moldboard. Slatted moldboards of iron and wood have been used to aid scouring. Late experiments with plastics such as nylon and Teflon fused to the surface of the moldboard show good scouring qualities and reduce the draft 15 to 25 per cent. The author could find no reference as to where high-frequency electrical vibrations had been tested as a scouring aid. In general, the shape and construction of the steel moldboard have been relied on more than anything else to obtain scouring qualities. The low incline and slight curvature of the blackland bottom shown in Fig. 10-4 have the best scouring qualities of the various solid moldboard shapes available.

The Design of the Plow Framework. To support the plow bottom or bottoms, there must be a framework consisting of beams, braces, crank arms to raise and lower the plow, arrangements for hitching or mounting

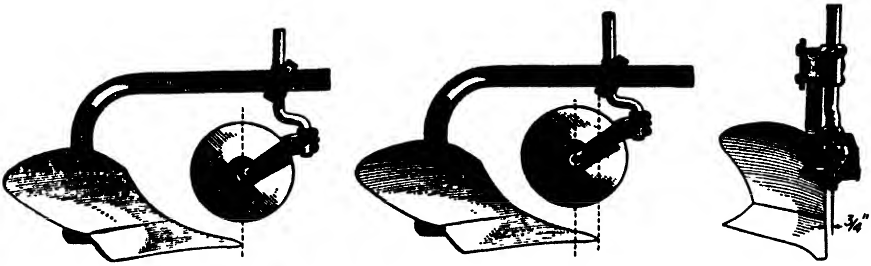


Fig. 10-24. Views of rolling colter showing proper setting in relation to the plow bottom. (*International Harvester Company.*)

the plow to the tractor, and power lifts, either mechanical or hydraulic. The designer must consider the size and strength of the steel members and fit them together to withstand severe stresses, both longitudinally and horizontally.

Accessories for Moldboard Plows. The moldboard plow bottom is a working unit in itself and is used extensively without accessories. There are a number of devices that can be used as aids and attachments to assist the bottom in doing a good job of plowing. The list of accessories includes gage wheels, colters, jointers, and trash-covering aids of hooks and wires.

Where the soil is soft, gage wheels are required if the plow is to maintain a uniform depth. They can be attached to the beam ahead of the bottom or to the side of the beam.

A colter is used to cut the furrow slice from the land and leave a clean wall. It also cuts through trash so the plow can cover it better.

The *rolling colter* (Fig. 10-24) is a round, flat steel disc which has been sharpened on the edge and suspended on a shank and yoke from

the beam. The edge of the colter may be either smooth or notched. It is so constructed that it can be adjusted up and down for depth and sidewise for width of cut. The proper setting of a rolling colter is shown in Fig. 10-24. This type of colter is used more than any of the others because it will leave a smooth furrow face and will also cut trash much better than the other types.

The *jointer* is a small irregular-shaped piece of metal having a shape similar to an ordinary plow bottom (Fig. 10-25). It is a miniature plow. Its purpose is to turn over a small, ribbonlike furrow slice directly in front of the main plow bottom. This small furrow slice is cut from the left and upper side of the furrow slice and is inverted, so that all trash on top of the soil is completely turned under and buried in the right-hand corner of the furrow.

The jointer is used not only by itself but also in combination with the rolling colter (Fig. 10-26). This gives a *combination rolling colter and jointer*. The rolling colter cuts the main furrow slice and all trash vertically from the furrow wall, and the jointer turns its miniature furrow slice as when working alone. The advantage of the combination rolling colter and jointer is that the rolling colter cuts all trash and allows the jointer to turn its furrow slice without any trash hanging around the shank. The performance of the plow at high speeds is greatly aided by the rolling colter and jointer.

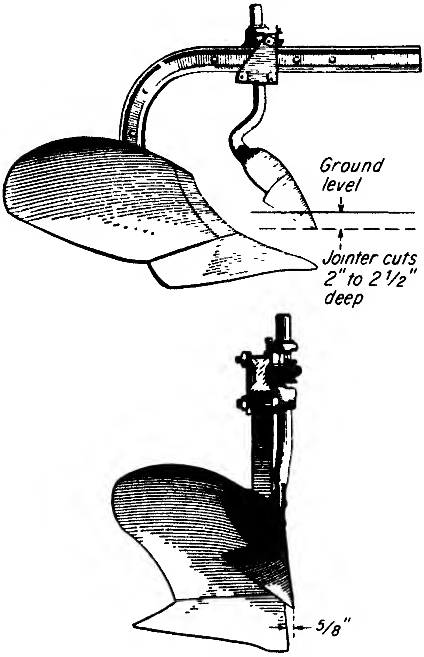


Fig. 10-25. Proper setting for a jointer. (*International Harvester Company.*)

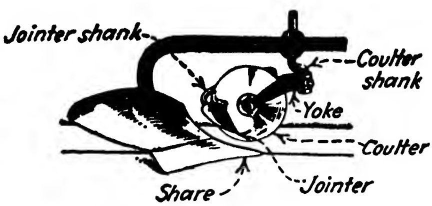


Fig. 10-26. Combination rolling colter and jointer, showing how the hub of the colter is set over the point of the share.

The regular *concave rolling disk colter* (Fig. 10-27) is a relatively new innovation in colter design. The concave blade cuts and turns a shallow furrow slice and, thus, does the work of both a jointer and rolling

disk colter. This type of colter is not recommended for hard and stony conditions.

The common type of weed hook consists of a rod attached to the beam and extending out to the front and side of the plow bottom (Fig. 10-28).

Fig. 10-27. Concave disk colter. (*Allis-Chalmers Mfg. Co.*)

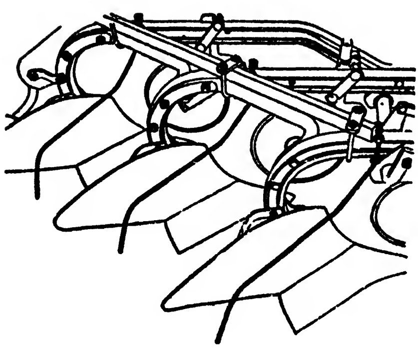


Fig. 10-28. Properly attached and shaped weed hooks are an aid in plowing under tall green vegetation. (*Iowa State Col. Bul.* P95.)

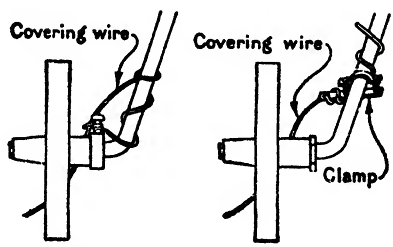


Fig. 10-29. Method of fastening covering wires to plow axle. (*U.S. Dept. Agr. Farmers' Bul.* 1690.)

The object is to bend the weeds over in such a manner that they will be completely buried in the bottom of the furrow. Smooth wires 10 to 12 feet long, fastened to the colter shank and to the axle of the furrow wheel, are of much value in covering trash and tall plant growth (Fig. 10-29). The wires should be rigidly fastened to reduce swinging and dragging under the bottoms when turns are made with the plow lifted.

Draft of Moldboard Plows. The draft of a moldboard plow is affected by many factors such as the type and shape of bottom, more especially the moldboard; the sharpness of the share; the over-all adjustment of the plow; the depth and width of furrow; and the many soil types and characteristics of the soil. The speed at which the plow is operated is an important factor affecting draft of plows. When all these factors are considered, there will be a wide range in the draft of any type or shape of bottom from field to field, depending on the type and condition of the soil. Thus, the draft may range from 5 to 12 pounds pull per square inch of furrow section.[5] A 14-inch bottom plowing 8 inches deep will turn a furrow section of 112 square inches. Assuming the draft is 8 pounds per square inch, then the draft for the bottom will be 896 pounds.

The draft of any plow can be determined by an instrument called a *dynamometer*, which registers the pull or draft of the plow over a measured distance. Then, knowing the rate of travel, the horsepower as well as the average draft per unit of the cross section of the furrow slice can be determined.

$$\text{Horsepower} = \frac{\text{force} \times \text{distance traveled in ft. per min.}}{33{,}000}$$

The dynamometer measures the total draft required for the plow. It should be kept in mind that the weight of the plow alone requires power to move it. Collins[6] states: "The draft of the plow on the ground is 18 per cent; draft due to turning furrow slice, 34 per cent; draft due to cutting slice, 48 per cent."

Thus, it is seen that practically 50 per cent of the total draft of the plow is used in cutting the furrow slice. A test was run to determine the effect of dull shares and sharp shares upon the draft of the plow. In a test on sandy-loam soil, the difference in draft of a sharp share was almost negligible. In a field of bluegrass sod, there was a difference of 14 per cent in favor of the sharp share. In soil that is soft and mellow, the sharpness of the share will not matter so much, but if there are many roots, or if the soil is comparatively hard or lacks moisture, a sharp share is to be advocated.

Effect of Speed on Draft. Where high performance is desired in plowing with tractor power, speed is highly important.

Results of the tests made in California by Davidson, Fletcher, and Collins[7] were as follows: "In clay loam speed 1 m.p.h.—draft, 100 per

[5] American Society of Agricultural Engineers Data: Crop Machines Use; I. Draft and Power Requirements of Crop Machines, *Agr. Engin. Yearbook*, 1954, p. 69.

[6] E. V. Collins, *Amer. Soc. Agr. Engin. Trans.*, 14:39, 1920.

[7] J. B. Davidson, L. F. Fletcher, and E. V. Collins, *Amer. Soc. Agr. Engin. Trans.*, 13:69, 1920.

cent. Speed 2 m.p.h.—draft 100 to 114 per cent. Speed 3 m.p.h.—draft 128 per cent. Speed 4 m.p.h.—draft 142 per cent." Tests in Iowa black-loam soil gave the following results: "Speed 1 m.p.h.—draft 100 per cent. Speed 2 m.p.h.—draft 117 per cent. Speed 4 m.p.h.—draft 126 per cent."

The conclusions were that an increase of the field speed of a plow with a general-purpose moldboard from 2 to 3 m.p.h. resulted in an increase of draft from 8 to 12 per cent, varying with the soil. Doubling the speed will result in an increase of draft from 16 to 25 per cent. The amount of work accomplished is increased from 50 to 100 per cent, respectively. It is to be remembered that practically 50 per cent of this task of plowing is cutting the furrow slice. The conclusions reached by Collins in his tests in Iowa in 1920 were that the increase in draft, due to speed, is applied to that part of the total which is required for turning and pulverizing. This varies with the speed from less than one-third to about one-half the total draft of the plow within a range of 2 to 4 m.p.h.

TABLE 10-1. RATE OF TRAVEL

Miles per hour	*Feet per minute*	*Miles per hour*	*Feet per minute*
1	88	3¾	330
1¼	110	4	352
1½	132	4¼	374
1¾	154	4½	396
2	176	4¾	418
2¼	198	5	440
2½	220	5¼	462
2¾	242	5½	484
3	264	5¾	508
3¼	286	6	528
3½	308		

Studies made in Ohio by Ashley, Reed, and Glaves[8] indicated that with two bottoms the average increase in draft due to increased speeds was 1.17 pounds per square inch of furrow slice for each mile per hour increase in speed.

Effect of Grade on Draft. When a tractor is on a grade, its effective drawbar pull is lessened 1 per cent for each per cent of grade. For example, the weight of the tractor ready for work with an operator and a three-bottom plow is approximately 7,600 pounds. To negotiate a 10 per cent grade with this outfit would require an additional power equivalent to a pull at the drawbar of 760 pounds.

[8] W. M. Ashley, I. F. Reed, and A. H. Glaves, Progress Report on Draft of Plows Used for Corn Borer Control, *U.S. Dept. Agr. BAE,* 1932.

DISK PLOWS

The disk[9] plow was brought out in an effort to reduce friction by making a rolling bottom instead of a bottom that would slide along the furrow. It cannot be said with authority that, after the extra weight is incorporated into the plow, it will have any less draft than the moldboard type. The results of the disk-plow usage, however, show that it is adapted to conditions where the moldboard will not work, such as the following:

1. Sticky, waxy, gumbo, nonscouring soils and soils having a hardpan or plow sole
2. Dry, hard ground that cannot be penetrated with a moldboard plow
3. Rough, stony, and rooty ground, where the disk will ride over the rocks
4. Peaty and leaf-mold soils where the moldboard plow will not turn the slice
5. Deep plowing

This type of plow is used in the South and North and very extensively in the Southwest and semihumid regions of the Middle West. It is of special value in Texas because of the large areas of soil having a close texture which will not scour on the average moldboard plow. Plow manufacturers call Texas a *disk-plow state.* There are large areas of this state, however, where the moldboard plow does work satisfactorily.

Tractor Disk Plows. Tractor disk plows are divided into trailing, semi-mounted, and integral-mounted types.

Trailing Disk Plows. The trailing disk plows can be divided into two types, *regular* and *one-way*.

Regular Trailing Disk Plows. As the name indicates, these plows are pulled behind the tractor (Fig. 10-30). The plow is a unit in itself and is attached to the tractor by a hitch that can be adjusted both vertically and horizontally. In the older models, the frame is arranged to the side and below the top of the disk bottoms. This is called a *side-frame* plow. Newer models of trailing disk plows have a high frame above the disk. This plow is called on *overhead* disk plow. Longer standards are required to attach the disk bottoms to the overhead frame than to the side frame. The high frame gives sufficient clearance for plowing in trashy fields. Arrangements are provided for adjusting the vertical angle of the disk, which influences penetration.

The trailing disk plow is provided with three wheels: two furrow wheels and a land wheel. The front furrow wheel is at the front end of the frame and is connected to the hitch to aid in guiding and turning the

[9] As used in this text, *disk* means a round, concave piece of metal while *disc* means a round, flat piece of metal.

plow. The rear furrow wheel is usually allowed to swivel on left-hand turns but is limited in its movement to the right so it will hold the plow in proper position when plowing. Both furrow wheels are inclined to hold the plow in position (Fig. 10-30). The land wheel is usually located toward the rear of the plow but slightly forward of the rear furrow wheel. The power lift is always a part of the land wheel. When plowing hard soils, additional weights on the wheels will help to hold and steady the plow. If desired, the wheels can be equipped with rubber tires. Levers and screw cranks provide a means of adjusting for depth and for leveling the plow. Hydraulic remote-control lifts can be obtained for

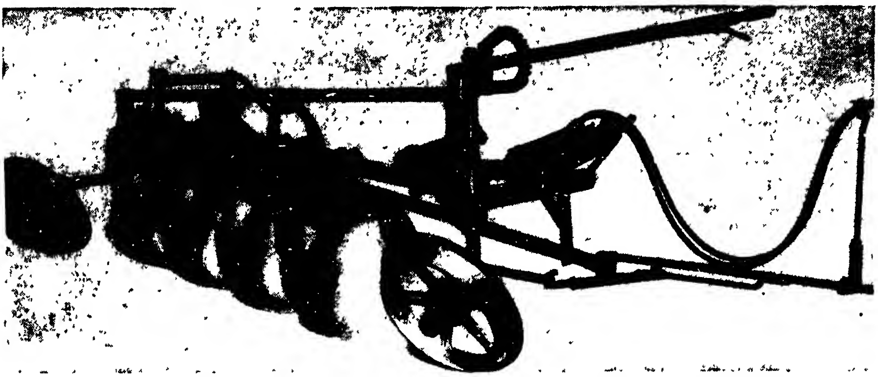


Fig. 10-30. Four-bottom trailing disk plow equipped with hydraulic remote-control cylinder to lift plow. (*International Harvester Company.*)

trailing disk plows. Heavy-duty disk plows can be obtained for deep plowing and for plowing in heavy soils.

Tiller or One-way Trailing Disk Plows. As shown in Fig. 10-31, the one-way disk plow is a combination of the principles of the regular disk plow and the disk harrow and is often termed a *wneatland, cylinder, harrow,* or *tiller plow.*

The one-way tiller plow was developed in the Great Plains area about 1927. It was designed primarily as a one-way disk harrow. As its use spread, farmers began to adopt it for shallow plowing. Improvements have made the tool into a popular and widely used plow. The speed of the plow should not be over 4 m.p.h. High-speed operation increases the power requirements, causes too much pulverizing of the surface soil, and does not leave trash on the surface to prevent wind erosion.

The one-way disk plow has the frame, wheel arrangement, and depth-adjusting devices of the regular disk plow, but the disk bottoms are assembled on a single shaft and turn as a unit similar to a gang of disks

on a disk harrow (Fig. 10-32). The disks may be spaced 8 or 10 inches apart. The number per plow may vary from two to thirty-five. The size will range from 20 to 26 inches. When ten disks are spaced 8 inches apart, the approximate cut will be 6 feet, but when ten disks are spaced 10 inches apart, the cut will be approximately 7½ feet. A plow with thirty-five disks will cut a strip about 20 feet wide.

Special features and uses of the one-way plow include (1) a seedbox attachment (Fig. 10-33) which permits the seeding of small grains and

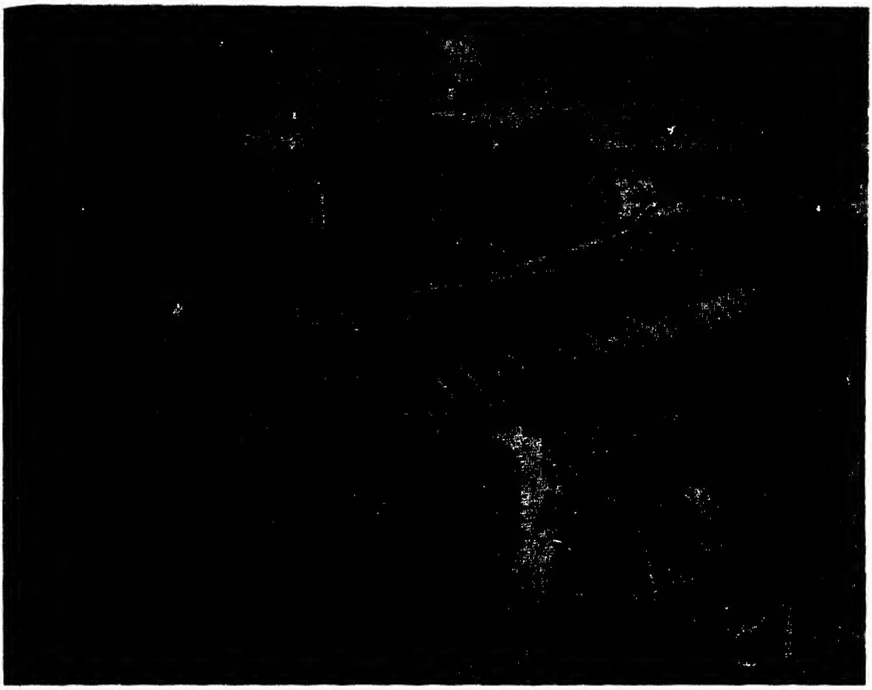


Fig. 10-31. Rear view of a one-way disk plow. (*Deere & Co.*)

grass, (2) removable sections of the gangs to reduce the size, (3) disks mounted eccentrically for the forming of pits and basins to conserve water and prevent wind erosion, and (4) the use of the one-way plow for the building of broad-based terraces.

Semimounted Disk Plows. The semimounted disk plow is also called a *direct-connected* plow. The front of this plow is connected to and mounted on the tractor, thus eliminating the front furrow wheel and the land wheel (Fig. 10-34). A furrow wheel supports the rear end. This close-coupled plow is compact and easy to handle. It is easy to maneuver because short turns can be made, enabling the operator to work close to fences. It can also be backed into corners. The rear wheel is automatically

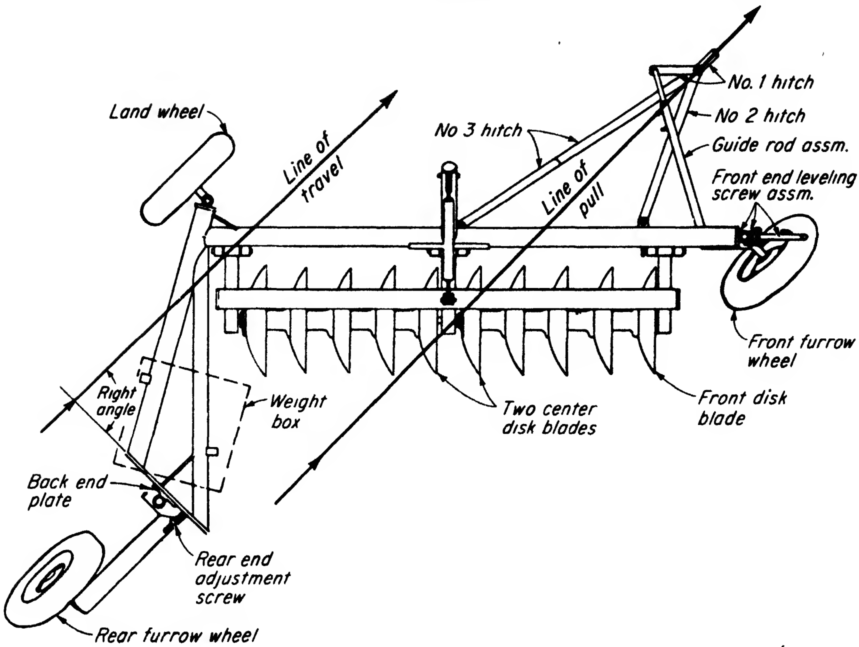


Fig. 10-32. Overhead view of one-way disk plow showing arrangement of frame and disk gangs. (*Schafer Plow Company.*)

Fig. 10-33. One-way disk plow equipped with seedbox attachment for seeding small grain. (*International Harvester Company.*)

controlled from the steering mechanism at the front of the tractor. These plows are built in three sizes according to the number of bottoms. A hydraulic lift raises the front of the plow high enough so it can be turned and transported easily. Depth of plowing is adjusted by the lever at the rear. Wheel weights and scrapers for the disks can be obtained.

Five-bottom semimounted two-way or reversible disk plows are now available.

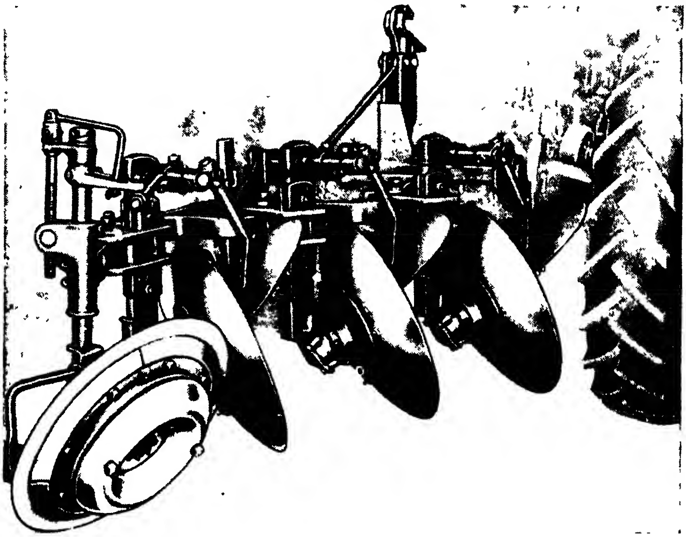


Fig. 10-34. A three-disk semimounted disk plow lifted by three-point hitch. (*Deere & Co.*)

Fig. 10-35. Five-bottom integral-mounted disk plow in lifted position. (*International Harvester Company.*)

Integral-mounted Disk Plows. The integral mounting of disk plows on the rear of a tractor so they could be lifted or picked up with hydraulic lifts was first thought to be impractical. This was true as long as the heavy weights were retained on the rear furrow wheel. Designers found that integral-mounted disk plows would give good performance if the weight was moved from the rear furrow wheel forward onto the frame. A rear furrow wheel on an integral-mounted disk plow may serve to counteract

side pressures, hold the plow in alignment, and act as a gage wheel for plowing depth. The depth in some makes is controlled by adjusting the hydraulic lift. Figure 10-35 shows a five-bottom integral-mounted disk plow.

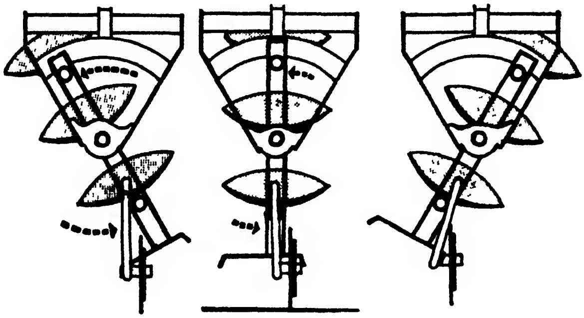


Fig. 10-36. Most reversible disk plows are reversed by moving the front of the plow to the right or left of center.

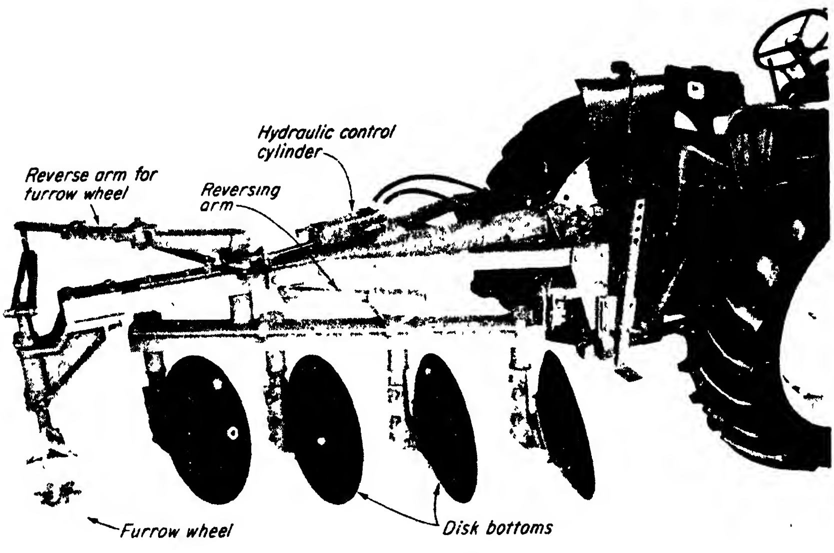


Fig. 10-37. Three-bottom two-way integral-mounted reversible disk plow. (*Deere & Co.*)

Figure 10-36 shows a two-way or reversible disk plow integrally mounted. The two bottoms are reversed by a lever or hydraulic arrangement that permits the bottoms to swing sidewise on a quadrant located on the beam above the front bottom (Fig. 10-37).

Special integral-mounted gangs of disks for bedding land and for barring off stubble or crop rows are shown in Fig. 10-38. The disks on a

Fig. 10-38. Four-row integral-mounted disk bedder. (*Deere & Co.*)

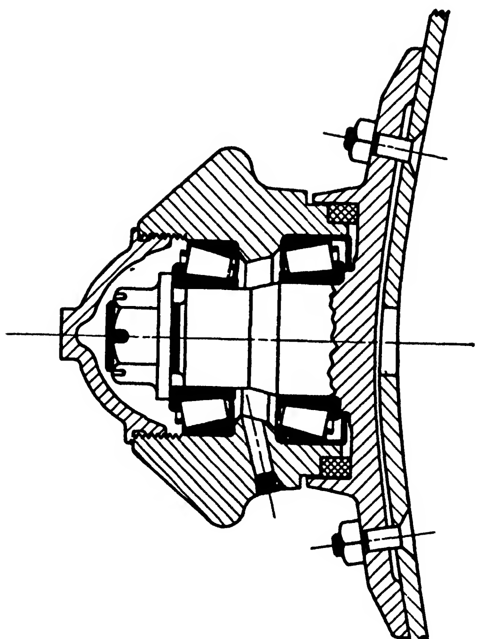


Fig. 10-39. Roller bearing for disk-plow bottom. (*Timken Roller Bearing Company.*)

gang may all be the same size, or they may vary in size. The gangs may be adjustable for pitch and gather and may also be reversed.

Integral-mounted border-making disks are available. The number of disks per gang varies from one to four. The diameter of the disk ranges from 20 inches where three and four disks are used to 28 inches where a single disk is used.

Design of Disk Plows. The disk-plow bottom is a perfectly round, concave disk of heat-hardened steel, sharpened on the edge to aid in the penetration of the soil. The size of a disk-plow bottom is the diameter of the disk and ranges from 20 to 38 inches. The average thickness of the steel for disk-plow bottoms is 3/16 inch for the smaller sizes and may be as much

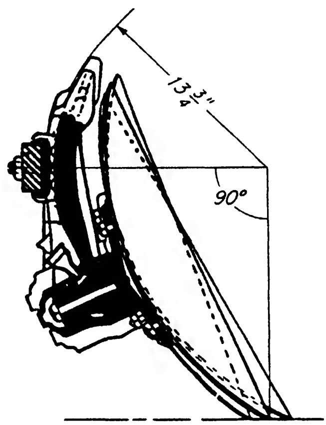


Fig. 10-40. Vertical angle of disk bottom can be easily changed.

as 3/8 inch for the larger sizes. The amount of concavity varies with both the different diameters and the same diameter as shown in Table 10-2.

Angling of Disk-plow Bottoms. The disk bottom is attached to a standard which may extend downward from the heavy steel beam. The disk rotates on a chilled-iron ball or roller bearing (Fig. 10-39). The standard is adjustable to give variable degrees of vertical and horizontal angle to the disk bottom.

The disk plow can be made to penetrate more easily when the disk is set more in a vertical position (Fig. 10-40). The flatter it sits, the less tendency there will be for it to penetrate. Further to enable the disk plow to take the soil properly, weight is added to the frame and wheels to force the plow into the ground. There is one great difference between moldboard and disk plows: the moldboard plow is pulled into the ground by the suction of the plow, while the disk is forced into the ground by added weight or force and by the suction of the disk due to the angle at which it is set.

The horizontal angle of the disk influences the width of the furrow slice and the tendency to roll. Disks set more nearly perpendicular to the direction of travel cut wider furrows and do not turn so freely as those set more nearly parallel to the furrow. When the disk plow is pulled forward, the disk will turn as a result of the action of the furrow slice upon it. The top of the disk is revolving to the tractor operator's left.

TABLE 10-2. SIZE, CONCAVITY, AND RADIUS OF THE AVERAGE DISK PLOW

Size, inches	*Concavity, inches*	*Size, inches*	*Concavity, inches*
20	2⅞	26	4½
23	3½	28	4¼
24	3⅜	28	5⅜
24	3¹¹⁄₁₆	32	4¼
26	3¾	32	6½
26	4	38	6½

SOURCE: R. C. Ingersoll, The Development of the Disk Plow, *Agr. Engin.*, 7(5):172, 1926.

The furrow slice, then, is cut by the left edge of the disk, brought under and up to the right, and then thrown out to one side. The furrow slice is pulverized to some extent when carried over the concave surface of the disk.

The Center of Resistance. The center of resistance on disk plows is closer to the furrow wall than on moldboard plows. Its location is to the left and below the center of the disk. The exact point varies with the vertical and horizontal angles, the depth, and the amount of concavity of the blade.

Accessories for Disk Plows. Disk-plow bottoms should be equipped with scrapers which can be adjusted to work from the center to the edge of the disk. With the aid of the scraper, it is possible to get greater pulverization of the furrow slice. It is also possible to invert the furrow slice and cover trash much better. Weights aid in forcing the disks into the soil and hold the wheel in the furrow to prevent the disks riding out of the soil when plowing extra-dry and hard soil. Most types of disk plows can be obtained with hydraulic lifts. Levers or screw cranks aid in leveling the plow and adjusting for depth.

Draft of Disk Plows. The disk plow is slightly lighter in draft than the moldboard when plowing under similar conditions and turning the same volume of soil. The type of soil is the greatest external factor to consider in the draft of any plow. In very hard ground, it is often necessary to add weight to the wheels to force the plow into the soil. Of course, the added weight will create more draft.

Factors incorporated in the plow are very important. The bearings of the disk-plow blade also affect the draft. According to tests conducted by

Hardy,[10] a plain cone bearing will pull 23 per cent heavier than a ball or roller bearing.

The type of scraper used to clean the disk will also affect the draft. Hardy's tests indicate that the revolving type gave slightly less draft than the spade type. Draft of disk plows is, of course, affected by the depth and width of the cut per bottom and for the complete plow.

ROTARY PLOWS

Rotary plows are discussed separately from moldboard and disk plows because they are of an entirely different design. They are neither moldboard nor disk plows. Shawl[11] states that the rotary plow was invented about 90 years ago. The rotary plow has been used in Europe for many years, but the American farmer has only recently become interested in this type of plow. The reason for this lack of interest was the high cost and the large power requirements. In general, rotary plows may be divided into three types: the pull auxiliary-engine, the pull power-take-off-driven, and the self-propelled garden type.

Pull Auxiliary-engine Rotary Plow. This rotary plow is pulled forward by a tractor but has the cutting knives driven by an auxiliary engine mounted on the frame of the plow. This type of plow is made in 4-, 5-, and 6-foot sizes and requires 60 to 90 horsepower. The cutting knives are mounted on a horizontal power-driven shaft. Tractor-propelled, auxiliary-engine-driven rotary cultivators are also available.

Tractor-mounted Power-take-off-driven Rotary Plow. The rotary plow shown in Fig. 10-41 not only is pulled forward by the tractor but has the cutting knives also driven by the tractor. This type is usually 3 to 4 feet wide and requires 10 to 15 horsepower for each foot of width. The cutting knives or tines are generally mounted on a horizontal power-driven shaft which operates at about 300 r.p.m. The knives on some machines are provided with a shock-cushioned friction clutch that prevents the knives from breaking when they come in contact with a rock or solid obstacle.

The Self-propelled Garden-type Rotary Plow. Some of the garden-type rotary plows have one drive wheel, while others have two (Fig. 10-42). They plow a strip 9 to 30 inches wide and are powered by 6- to 15-horsepower engines. They can be operated at two speeds forward: low, ½ to 1 m.p.h.; high, 1 to 2¼ m.p.h. The reverse speed is ¾ to 1½ m.p.h. Some garden-type rotary plows can also be used for cultivating vegetable crops. The narrow width of 17 inches or less makes it possible to plow narrow strips in a garden where single rows of vegetables have been removed.

[10] E. A. Hardy, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

[11] R. I. Shawl, Rotary Plowing as a Means of Seedbed Preparation, *Farm Impl. News*, 67(6):50–53, 1946.

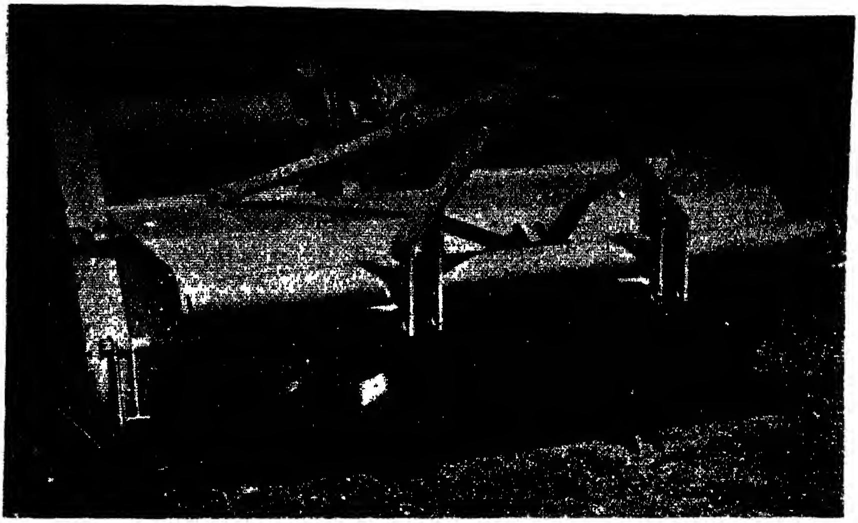


Fig. 10-41. Power-take-off-driven rotary plow, showing cutting knives mounted a horizontal shaft. (*Utility Tool and Body Co.*)

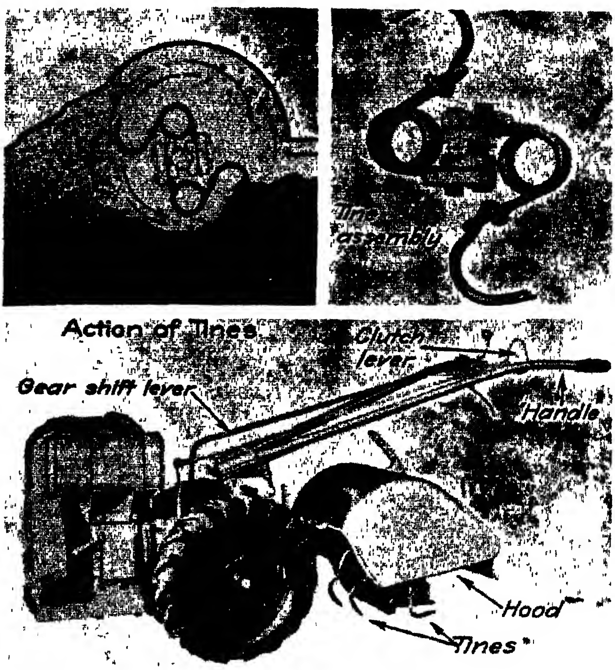


Fig. 10-42. Rotary plow of the garden-tractor type. (*Utility Tool and Body Co.*)

CHISEL AND SUBSURFACE PLOWS

The Chisel Plow. The chisel-type plow is a tool with a rigid curved or straight shank with relatively narrow shovel points. It may be termed a heavy-duty deep cultivator. The soil is stirred more or less in place (Fig. 10-43). The standard or shank is constructed of nickel-alloy heat-treated spring steel that is given a long, gradual curve flatwise to permit a slight spring action. The standards are arranged on heavy frames in two or three staggered rows to permit trash to pass between them without choking. Most chisel plows are provided with coil cushion springs in conjunc-

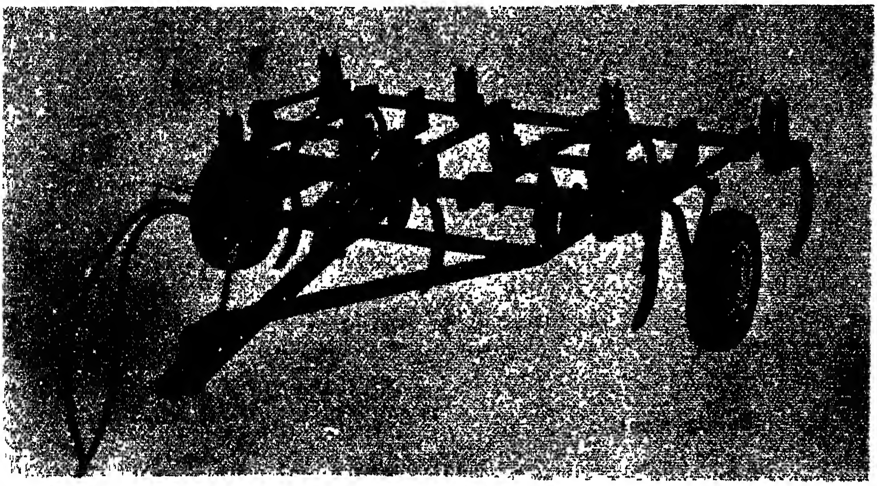


Fig. 10-43. Front view of trailing hydraulically lifted chisel plow equipped with spring-loaded shanks. (*Deere & Co.*)

tion with the clamps. This permits the ground tool to swing back and up and to unhook the point (Fig. 10-43). The furrows may be as close as 12 inches or as wide apart as 2 to 3 feet. The depth of plowing may be as shallow as desired or as deep as 18 inches or more.

Some types of chisel plows are available in sizes ranging from 5- to 45-foot widths. On some of the larger plows the outer sections can be folded up on the center section. This aids in transporting the tool. Pneumatic-tired wheels control the depth or serve for transportation. Hydraulic lifts are provided for all sizes of plows.

As the soil is broken by stirring, it is not inverted and pulverized to the extent that moldboard and disk plows crush the soil. Therefore, the chisel plow is often used to loosen hard, dry soils before the regular plow is used. The chiseling and stirring operation does not throw enough soil to cover trash completely. Hence, the chisel-type plow is used for stubble-mulch or subsurface tillage practices. This type of plow is also useful in

breaking up hard layers of soil just below the regular plowing depth. This layer of soil is called by several names, such as *hardpan* and *plow sole*. Special plow shovels, lister shovels, sweep and knife assemblies (Fig. 10-44), and seeding attachments make it possible to do many jobs with the chisel-type plow.

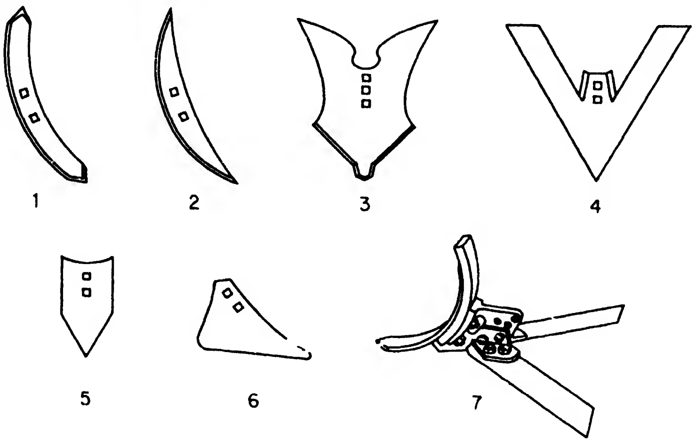


Fig. 10-44. Types of points that can be used on chisel standards: 1, chisel; 2, spike; 3, furrower; 4, sweep; 5, shovel; 6, drill shoe; 7, combination chisel and sweep.

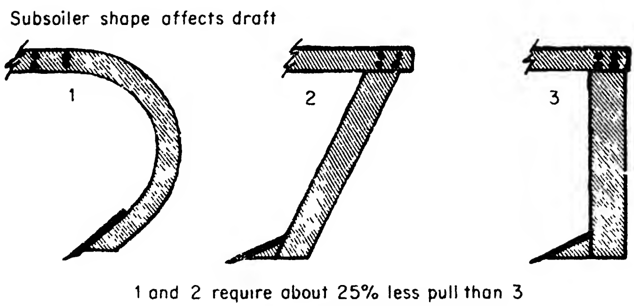


Fig. 10-45. Three types of subsoiling standards. (*Cornell Univ., Agron. Mimeo.* 61-2.)

Subsoilers. Subsoil plows are built heavier than the chisel plows, since they are used to penetrate the soil to depths of from 20 to 36 inches. Tractors of 60 to 85 horsepower may be required to pull a single standard ripping through a hard soil at a depth of 3 feet. The standard on subsoil plows is usually long and narrow with a heavy, wedge-like point (Fig. 10-45). One standard is generally used for the deeper depth, but two or more can be used for shallower operations. Large hydraulic cylinders are provided for lifting the plows. In some types of poorly drained soils, a

mole ball shaped somewhat like a torpedo is drawn through the soil behind a subsoil standard. The mole ball leaves a tunnel which serves as a drainage channel for water.

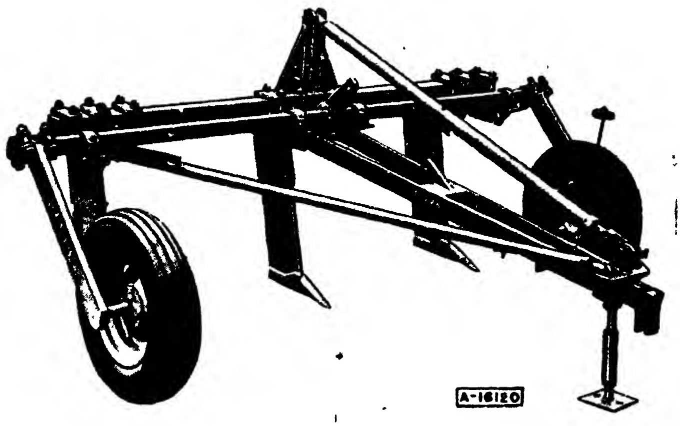


Fig. 10-46. Trailing subsoiler equipped with three straight standards. (*J. I. Case Company.*)

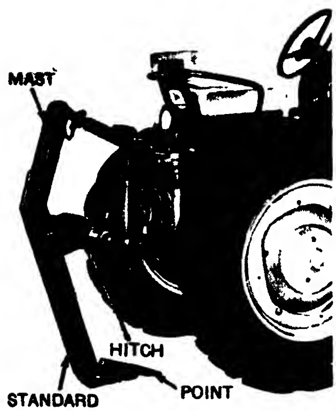


Fig. 10-47. Mounted-type subsoiler with one standard. (*Deere & Co.*)

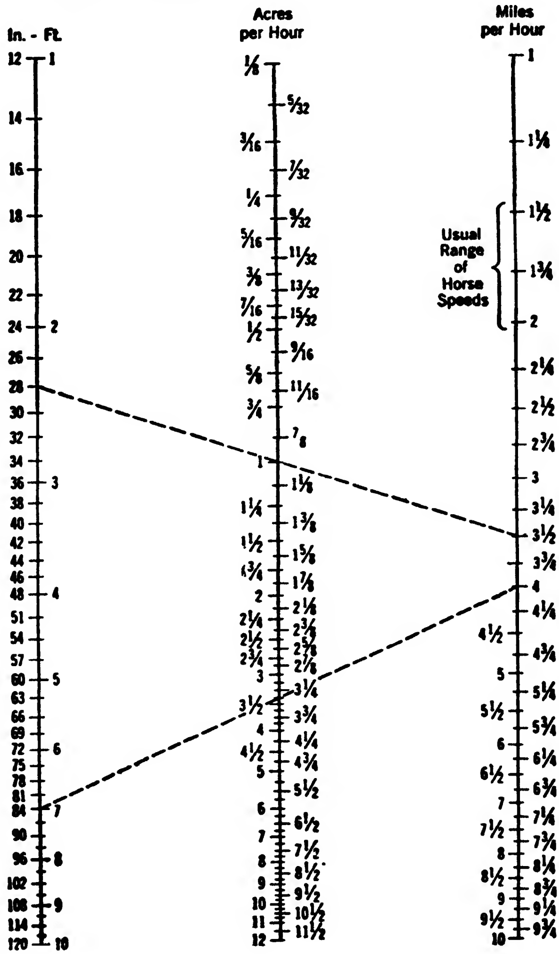
Subsoil plows are available in both trailing and mounted units (Figs. 10-46 and 10-47). Subsoil standards can also be attached to regular tractor tool bars.

Generally, the subsoiler plow is a heavy-duty tool designed to operate below the normal depth of tillage and to loosen the soil by lifting or displacement.

RATE OF PLOWING

One 14-inch plow bottom pulled at the rate of 2½ m.p.h. will plow approximately 11/32, or 0.3, acre in 1 hour. Some time, however, must be allowed for turning, which will depend on the shape and size of the field and how it is laid out. For example, with a two-plow outfit in a field 80 rods long, where lands of average width are struck out and the turning is done on headlands, about 6 per cent of the time is spent in turning at the ends. Table 10-3 shows the acreage plowed with plows of different width when drawn at different speeds.

TABLE 10-3. CHART SHOWING ACRES COVERED PER HOUR WITH DIFFERENT WIDTHS OF IMPLEMENTS AT VARIOUS SPEEDS



A four-plow outfit, of course, will accomplish about twice as much as the two if both are run at the same speed, and a six-plow outfit twice as much as the three-plow outfit. One acre contains 43,560 square feet or 160 square rods. A 14-inch furrow 1 mile long equals 6,160 square feet.

The number of acres plowed per day depends upon the width of strip plowed, the rate of travel (speed), and the length of time operated.

This can be expressed in the following formula, which allows about 17.5 per cent of the operating time for loss in turning:

$$\text{Acres per 10-hour day} = W \times \text{m.p.h.}$$

where W = width of strip plowed
m.p.h. = miles per hour or rate of travel

Example: How long will it take to plow a 40-acre field with three 14-inch-bottom plows pulled by a tractor at 3 m.p.h.?

Three 14-inch bottoms cut a strip $3\frac{1}{2}$ feet wide.

$W \times$ m.p.h. $= 3\frac{1}{2} \times 3 = 10.5$ acres plowed in a 10-hour day
$40 \div 10.5 = 3.8$, or almost 4 days required to plow the 40 acres

GIANT PLOWS

In some areas where good land has been covered by blow sand or flood deposits, giant plows are used to bring up good soil from depths of 2 to 6 feet and lay it on top of the sand (Fig. 10-48).

HITCHES FOR PLOWS

A plow or implement may be well designed and built of high-grade materials, but unless it is properly hitched to the prime mover, or the power unit, it cannot give the highest possible performance. The hitch may be simple, consisting of only one or two parts, or it may consist of a multiplicity of bars, braces, angles, linkages, and levers arranged to absorb certain vertical and horizontal forces. The problem is to get all the pulling forces of the power and the resisting forces of the load in equilibrium or nearly so, both vertically and horizontally.

Moldboard Trailing Plow Hitches. The perfect hitch for a trailing plow or any other trailing tool would be to have the center of the pulled load directly behind the center of the power unit. This condition is rarely obtainable because of the varying widths of the different sizes of tractors and the different widths and sizes of the plows or pulled units.

Vertical Principles. Above, under Plow Design, the various forces that act on a single plow bottom were discussed. Under Hitches for Plows these principles must be expanded and applied to plowing units from two to six or more bottoms.

Clyde[12] states that "the location of the combined backward and vertical resistance is important for deciding where the pull should be applied." Under average soil conditions, he found that the vertical center of resistance of a moldboard plow is a little below the surface and *above the share point.*[13] Figure 10-49 shows the points of resistance for a two-bottom plow at *B* and *C*, while the center of load and point of pull for the two bottoms are at *G*. The tractor drawbar is shown at *A*. The vertical line of pull should be a straight line between *A* and *G*. Therefore, the beam must be extended forward and provided with hitch plates that

Fig. 10-48. Giant moldboard plow plowing a furrow 4 feet deep and 2½ feet wide. (*Caterpillar Tractor Co.*)

extend downward to the line *AG* at *F*. A string stretched from the tractor drawbar *A* to the center of resistance *G* will show where the hitch bar of the plow should be placed.

If the hitch at *F* (Fig. 10-49) is above the line of pull, the bottom will tend to run on its nose, causing excessive wear on the share and undue strain on the axle and wheel bearings. Should the hitch at *F* be below the line of pull, there will be a lifting action on the front of the plow and the bottoms will tend to run shallow, particularly in hard ground.

The Vertical Line of Draft. From the above description of vertical forces it is seen that the vertical line of draft or line of pull is a straight

[12] A. W. Clyde, Mechanics of Farm Machinery, *Farm Impl. News*, January–March, 1944.

[13] Most literature shows the vertical center of resistance located at the same point as the horizontal center of resistance.

line from the center of the load through the point where the drawbar is attached to the plow to the point where the drawbar is attached to the drawbar of the tractor (Figs. 10-49 and 50).

Horizontal Principles. The balancing of the horizontal forces for various sizes of tractors and plows is the most important and the most difficult of

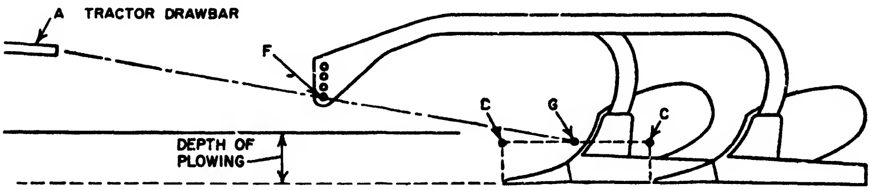


Fig. 10-49. The vertical center of resistance for a two-bottom moldboard plow is located above the share. The vertical line of pull should be a straight line from the center of load *G* through *F* to *A*. (*A. W. Clyde, University of Pennsylvania.*)

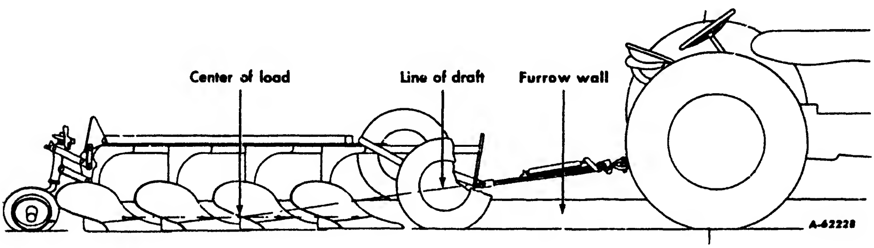


Fig. 10-50. The correct line of draft for a four-bottom trailing moldboard plow. (*International Harvester Company.*)

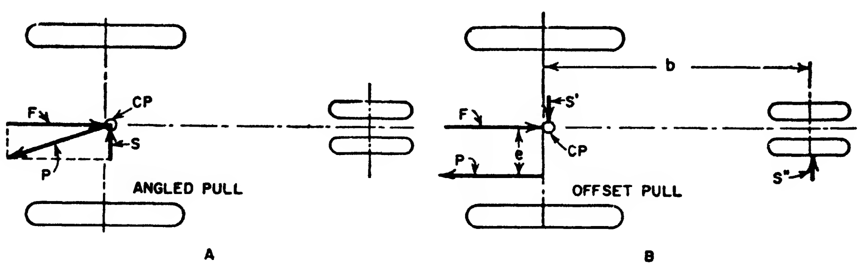
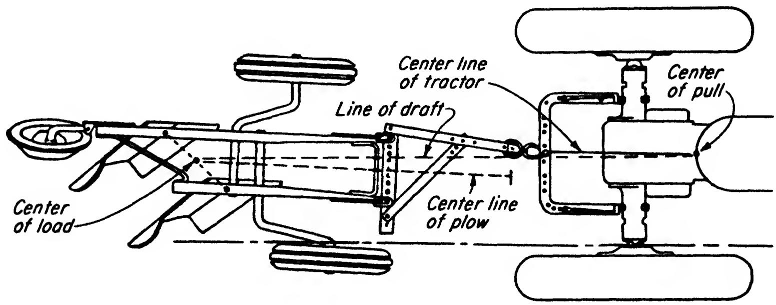


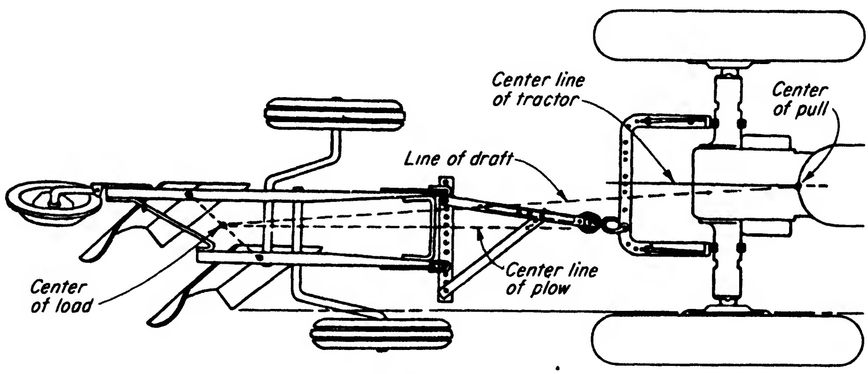
Fig. 10-51. Forces acting on a tractor when the center of the load is to the right of the center of pull. The pull *P* is at an angle in *A*, while in *B* the pull is offset and straight back. (*A. W. Clyde, University of Pennsylvania.*)

the hitching principles. The objective in the horizontal hitch is to determine the center of pull, or center of power, and the center of the load, or the center of the trailing unit, and arrange the hitch so the center of load is as nearly as possible directly behind the center of the power unit (Fig. 10-51).

The Horizontal Line of Draft. The horizontal line of draft should be a straight line from the center of resistance or load to the point where the plow drawbar is attached to the tractor drawbar. As shown in Fig. 10-52 the line of draft in the two-hitch arrangement does not follow the plow drawbar. This is because of the difference in the widths of the tractor and plow. The drawbar of the plow is held at an angle in an effort to



Sidedraft is all on the plow in this illustration Strain is on the rear axle and wheel—landsides will wear rapidly, load is increased and plowing will be of poor quality.



In this illustration sidedraft is all on the tractor. Tractor is difficult to steer, and it may be impossible to keep the front wheel out of the furrow.

Fig. 10-52. Two hitch arrangements for a two-bottom trailing moldboard plow drawn by a row-crop tractor. (*International Harvester Company.*)

bring the center of the load directly behind the center of the power or tractor and prevent side draft.

Center of Power. The center of power is often described as the *true point of hitch* or *center of pull.* Whatever the term used, the point referred to is the center of the power, which is chiefly horizontal, but the vertical forces must also be considered (Fig. 10-52). On a tractor, this is the point where the front end of the drawbar is attached, which is always the middle of the tractor halfway between the wheels. In most tractors,

the rear end of the drawbar can be swung sidewise to compromise the hitch on the tool. Such a drawbar is termed a *swinging drawbar.* It is useful when an angle pull is required.

Center of Load or Resistance. The factors involved in finding the center of resistance of a single moldboard plow bottom were discussed in detail in connection with the design of a moldboard bottom. It should be recalled that the center of resistance for a single bottom is located on the face of the bottom to the right of the shin, a distance equal to about one-fourth the width of the plow or width of cut (Figs. 10-21 and 10-23). When two 14-inch bottoms are used together, the center of load for the plow will be approximately halfway between the center of resistance of

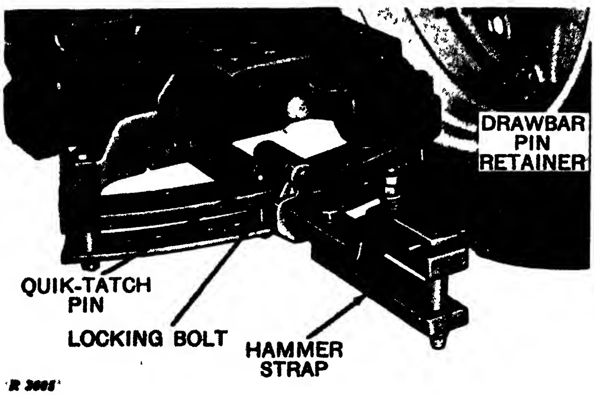


Fig. 10-53. Swinging drawbar on a tractor. (*Deere & Co.*)

the two bottoms, or one-half the width of the second bottom, which is 7 inches added to the $10\frac{1}{2}$ inches for the first bottom. The center of the load for the two bottoms is $17\frac{1}{2}$ inches to the left of the wing of the first bottom. Thus, if three 14-inch bottoms are used, the center of load will be $10\frac{1}{2} + 7 + 7$ or $24\frac{1}{2}$ inches from the wing of the first bottom. For each 14-inch bottom added, the center of load moves 7 inches to the left.

Side Draft or Side Pull. If the center of the load is directly behind the center of the pull or power, there should be little or no side draft or side pull (Fig. 10-51*A*). If, however, the center of the load is a few inches to the right of the center of the power, there will be side draft or pull (Fig. 10-51*B*). When a swinging drawbar (Fig. 10-53) is used, the pull will be through the angle *P*. Part of the side pull of the load tends to pull the tractor sideways. In this arrangement the center of pull *CP* is located at a point where the side forces *S* and the forward pull of the tractor *F* meet. Where the line of pull is through *P*, practically all the side force is carried by the rear tractor wheels.

If the point of hitch is moved to the side on the tractor drawbar, as in Fig. 10-51*B*, the line of pull is straight back but offset instead of angled as in Fig. 10-51*A*. In this case, the offset pull tends to rotate the tractor clockwise. That is, the rear of the tractor is being forced to the left while the front of the tractor is being forced to the right. The principles of the horizontal hitch are shown in Fig. 10-52.

Hitching of Semimounted Plows. As described above and shown in Fig. 10-14, the semimounted moldboard plow is connected directly to the tractor, but part of the weight of the plow is supported by a rear furrow wheel. The plow can be attached to the tractor by either a two-point connection or a three-point linkage arrangement (Figs. 10-14 and 10-54). Some makes of semimounted plows are equipped with a land wheel which aids in keeping the plow level. Where there is no land wheel, all the depth-control and leveling adjustments are provided in the hitch. The instructions in the operator's manual should be followed in making adjustments.

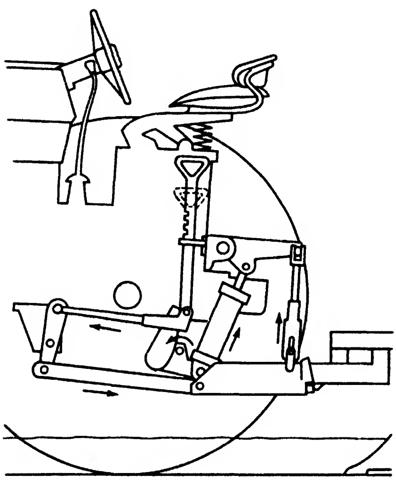


Fig. 10-54. Two-point hitch with hydraulic lift and fast-coupling arrangement. (*International Harvester Company.*)

Hitching of Integral-mounted Plows. The principles of hitching the trailing plow will also apply to the mounted plow. The hitching, however, is not left to the plowman because the design engineer necessarily had to establish the points of hitch and build the plow to suit a particular size and make of tractor. The plowman, therefore, has only to adjust the spacing of the rear tractor wheels to give the correct width of cut for the front bottom. Each of the tractor wheels should be adjusted an equal distance from the center of the tractor to keep the center of pull in the correct relation to the line of pull.

The designer of mounted plows, however, must consider the problems of vertical forces. A well-designed depth-regulating device must be provided. Trailing plows were built heavy to aid the penetration of the soil. Mounted plows must be built of strong but lighter materials to avoid overloading the tractor. The design engineer must have a good knowledge of mechanics and also a good conception of the reactions to be expected from soil types. Some mounted plows pull from a single point, but most designers use a three-point linkage (Figs. 10-55 and 10-56). The plow is

lifted by hydraulic power. In some plows the depth is adjusted by hydraulic controls.

The plow is equipped with a crossbar which extends across the front of the plow. The two lower hitch links on the tractor are connected to

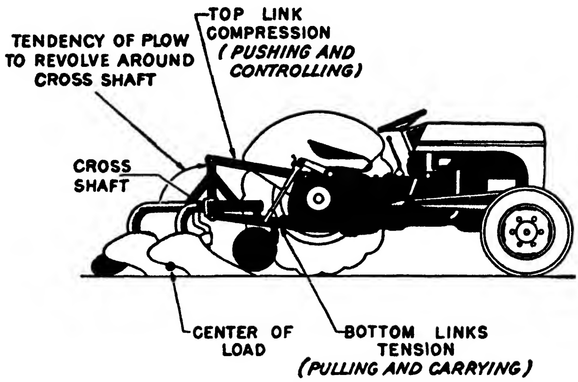


Fig. 10-55. A three-point hitch linkage that utilizes the resistance and weight of the soil to increase rear-wheel traction. (*Massey-Ferguson Ltd.*)

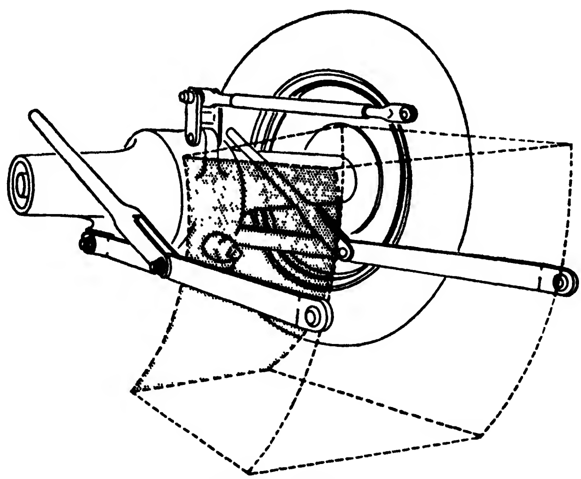


Fig. 10-56. Three-point hitch showing range of movement of the lower hitch bars. (*Amer. Soc. Agr. Engin. Yearbook*, 1962.)

the ends of the crossbar. The upper hitch link on the tractor is attached to a single or double bracket that extends upward from the crossbar. Adjusting the crossbar sidewise controls the width of cut.

The lower link bars are adjustable for length and height. This provides a means for leveling the plow sidewise and for depth control. The suction of the plow is controlled by adjusting the upper link.

Most mounted two-way or reversible moldboard plows are attached to the tractor by means of the three-point hitch. The adjustments for lifting, leveling, and depth control are the same as for the regular moldboard plow.

Disk-plow Hitching. The principles of hitching trailing moldboard plows are also applicable in hitching trailing disk plows. However, different hitch adjustments are necessary to obtain correct vertical and horizontal

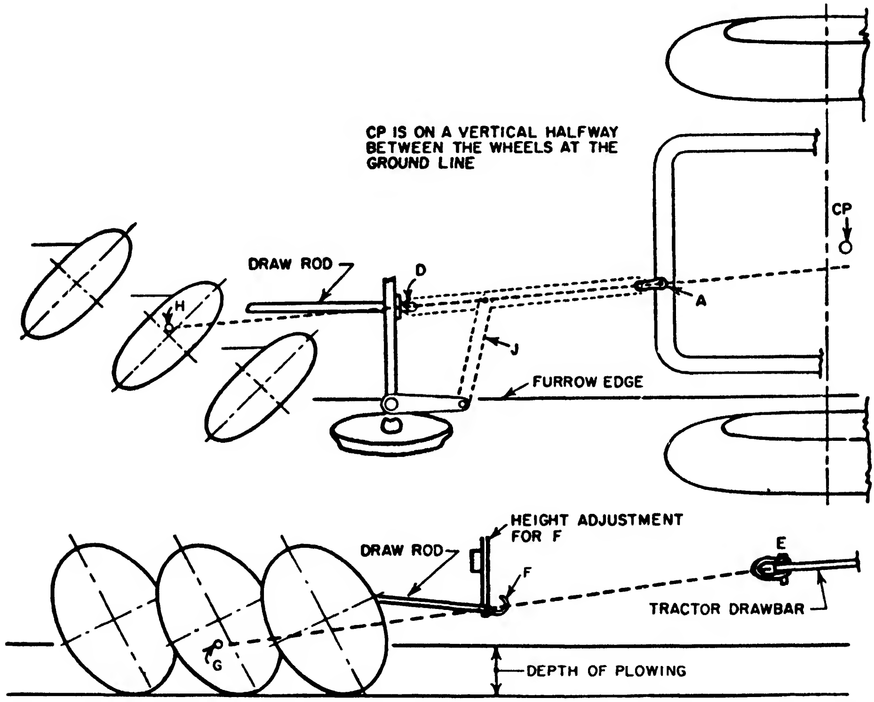


Fig. 10-57. Horizontal and vertical principles of hitching a disk plow. (*Pa. Agr. Ext. Cir.* 259.)

hitching. The vertical hitch is quite simple, because the hitch bar can be adjusted up and down on the plow so there will be a straight line from the tractor drawbar through the plow connection to the center of load of the plow (Fig. 10-57).

The center of resistance for a single disk is generally slightly below and to the left of the center of the disk. In operation, it will be slightly below the surface of the furrow slice. When two disks are used, the center of load will be halfway between the center of resistance for each of the two disks (Fig. 10-57). As the number of disks is increased, the center of load will be the average for all the disks, or the center of cut as measured on the ground.

When a trailing disk plow is hitched, the center of load should be as nearly as possible directly behind the center of pull or the power unit. For a narrow-tread tractor, place the tractor and plow in position for hitching, stretch a string from the center of pull on tractor drawbar to the center of load of the plow (Fig. 10-57). Then adjust the drawbar or hitch bar of the plow over the string from tractor drawbar to the plow clevis. If the tractor has a wide tread, stretch the string from the center of load of the plow to the tractor at a point about 3 inches to the right of the center of pull. Then adjust the draw rod over the string. The front

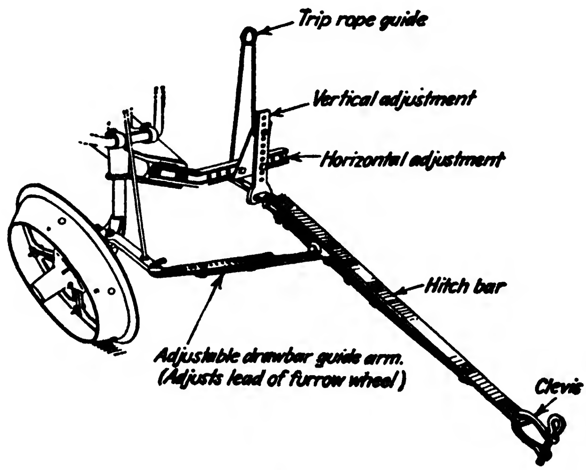


Fig. 10-58. A disk-plow hitch.

furrow wheel is adjusted by the guide arm so that it runs straight ahead or with a slight toe-out.

It is sometimes desirable to change the total width of cut of a disk plow. *To change to a narrower cut, the hitch on front of the plow is moved to the left.* This causes the front of the plow to move to the right and the rear to swing to the left (facing the front of the plow), causing the disks to fall more in line or to *trail.* Since the front furrow wheel is held in position by a guide arm (Fig. 10-58) connected to the hitch bar, it is necessary to adjust this arm whenever the hitch bar is moved either to the right or to the left. *To change to a wider cut, the hitch bar is moved to the right on the plow.* This will cause the rear of the plow to swing to the right so that each of the disks cuts more. The front of the plow is held in position by giving the front furrow wheel a lead toward the furrow wall.

Hitching the One-way Disk Plow. The hitch arrangement for a one-way disk plow is slightly different from that of the regular trailing disk plow,

but the same principles of horizontal and vertical forces are involved. The gang of disks is set at about a 45- to 50-degree angle to the direction of travel, while the beam of the regular disk plow is set at an angle of 30 to 35 degrees. The center of load for the entire plow will be farther from the first furrow for the larger plows. Therefore, a horizontal clevis bar extends across the front of the plow to the left and beyond the line of pull (Fig. 10-59). Near the outer end of the horizontal clevis bar is a drawbar that extends back to points about midway and to the rear of the frame or gangs. These bars keep the disks from trailing.

Two types of hitches are used on one-way plows, the figure-A type and the figure-four type (Figs. 10-59 and 10-60). The free swing end of the

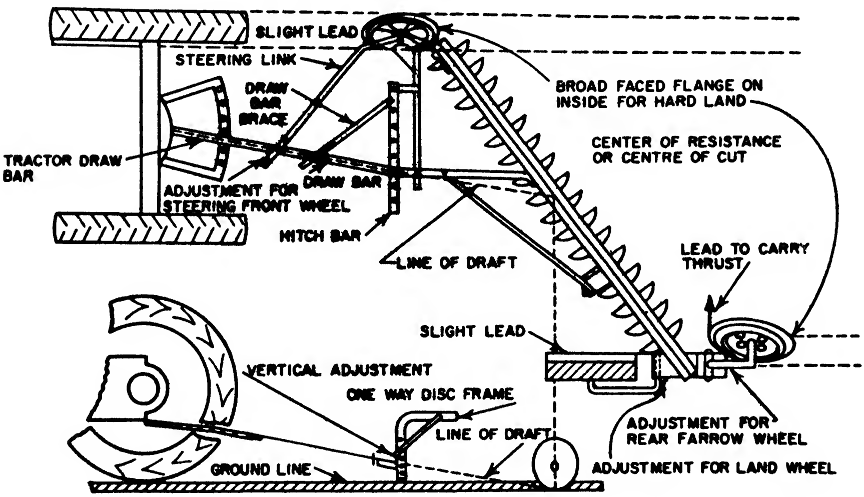


Fig. 10-59. Horizontal and vertical hitch for a one-way plow. (*Kansas Engineering Extension Department.*)

figure-A type should be approximately in line with the line of pull for the plow. For the figure-four, the long hitch bar should be in line with the center of pull.

The center of load for a one-way plow having small disks with a shallow dish is approximately one-half the width of cut. Larger disks with a larger dish have the center of load farther toward the plowed ground but never closer to the furrow than one-third the width of the cut. The vertical center of load is at the same point as the horizontal center of load but about one-half the plowing depth.

It is important that the hitch bar from the plow clevis to the tractor drawbar be in line with the vertical line of pull. A wide range of vertical adjustment is provided on one-way plows. If the tractor drawbar is too

high or the hitch bar too high on the plow, there will be a downward pull on the plow. This will throw excessive weight on the front furrow wheel and the frame will be tipped forward, which will reduce the weight on the rear furrow wheel. The reduction in weight on the rear furrow wheel will tend to let it climb out of the furrow, and the plow will swing out of

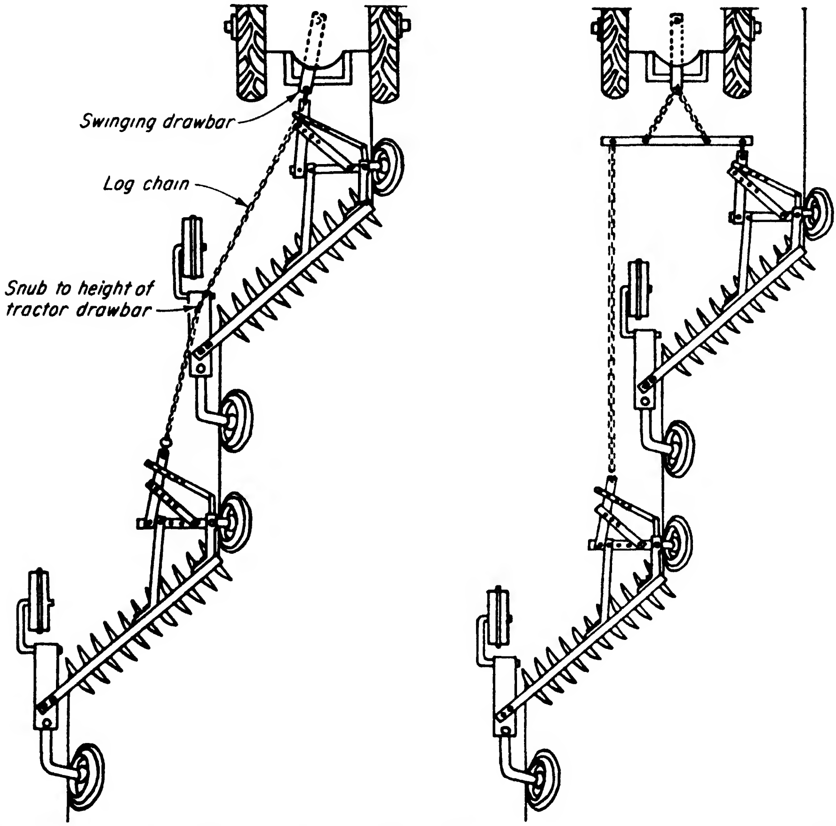


Fig. 10-60. Two types of drawbar hitches used on one-way plows—and two methods of hitching two one-way plows in tandem. (*Kansas Engineering Extension Department.*)

line. On some one-way plows, it may be necessary to add an extension to the vertical-adjusting bar to get the hitch bar at the plow low enough to prevent pulling down on the front end. The one-way plow generally operates best with a swinging tractor bar, as it permits shorter turns.

Multiple-unit and Tandem Hitches. Many farmers who have large tractors often prefer to use two to three medium-sized one-way plows rather than one large unit. Multiple-unit hitches for one-way plows are shown in Fig. 10-60.

Tandem hitching is used where one or more units performing different operations are trailed one behind the other. A plow may be followed by a disk harrow or a spike-tooth harrow. A tandem disk harrow is often used behind power-operated stalk cutter-shredders.

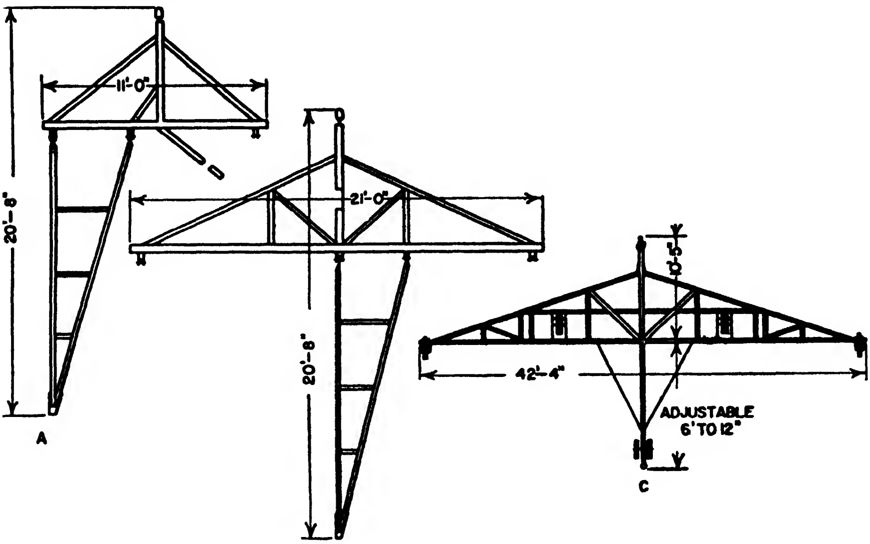


Fig. 10-61. Three multiple-implement hitches: *A*, hitch frame for two implements; *B*, frame for three implements; *C*, frame for three, four, five, or six implements. (*Caterpillar Tractor Co.*)

Fig. 10-62. Hitch assembly and spring release for two-bottom plows. (*J. I. Case Company.*)

Offset hitches are used for trailing a clod crusher to the side of a plow or a trailer beside a corn picker.

Multiple-width hitches are used when several units of the same kind are used to cover wide swaths, such as harrows, grain drills, and planters

(Fig. 10-61). On some of the larger farms, the swath harrowed or seeded may be as wide as 40 feet.

Cushion and Spring-release Hitches. A hitch that will release the plow or absorb a heavy shock load is needed where there are buried stones, stumps, and roots (Fig. 10-62). The most suitable type of cushion hitch has a declutching device that disengages the tractor clutch. But with the kinetic energy of the moving tractor, it can still cause serious damage. Hitches are being developed that will release the plow or absorb the shock hydraulically as well as declutch the tractor and apply the brakes simultaneously. Cushion and release hitches are not required on disk plows, as the disks will ride over stones and buried stumps.

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QUESTIONS AND PROBLEMS

1. Define primary tillage and list types of equipment used.

2. Draw sketches of the various kinds of furrows and name their parts.

3. Name the types of moldboard plow bottoms and explain the differences and uses.

4. Discuss the functions, advantages, and disadvantages of (*a*) two-way plows and (*b*) middlebreaker plows.

5. Discuss the advantages and disadvantages of trailing and integral-mounted plows.

6. Discuss the various factors involved in the design of moldboard plow bottoms.

7. Determine the acres plowed per hour when a tractor is operating at 3.5 m.p.h. and is pulling four 14-inch moldboard bottoms at a depth of 5.5 inches. What will be the total draft in pounds pull, if there is a draft of 8 pounds per square inch? How many acres can be plowed in 10 hours when the field efficiency is 78 per cent.

8. Discuss the conditions under which it may be advantageous to use a disk plow.

9. Explain the differences in design of the one-way and the regular disk plows.

10. Discuss the use of rotary and chisel plows.

11. Explain the vertical and horizontal principles involved in hitching a trailing moldboard plow equipped with four 14-inch bottoms to a tractor on which the inside walls of the tires are 67 inches apart.

12. Discuss the principles of the three-point hitch for integral-mounted plows.

13. Explain why the center of resistance is not always a fixed point on a moldboard plow bottom.

14. Define vertical and horizontal lines of draft.

15. Define side draft.

SECONDARY TILLAGE EQUIPMENT

11

The term *secondary tillage* as used in this discussion means stirring the soil at comparatively shallow depths. In many cases secondary tillage follows the deeper primary-tillage operation. It is possible to use some of the primary-tillage tools to do secondary-tillage operations. For example, the one-way plow and certain types of chisel plows can be adjusted and equipped with attachments to till the soil at shallow depths.

The general objectives of secondary tillage are stated as follows:

1. To improve the seedbed by greater pulverization of the soil
2. To conserve moisture by summer-fallow operations to kill weeds and reduce evaporation
3. To cut up crop residue and cover crops and mix vegetable matter with the top soil
4. To break up clods, firm the topsoil and put it in better tilth for seeding and germination of seeds
5. To destroy weeds on fallow lands

There are many types of machines that can be used for secondary tillage. They are the various types of harrows, rollers and pulverizers, and tools for mulching and fallowing.

HARROWS

A harrow is an implement used to level the ground and crush the clods, to stir the soil, and to prevent and destroy weeds. Under some conditions,

harrows can be used to cover seeds. There are three principal kinds of harrows, namely, the disk, the spike-tooth, and the spring-tooth.

Research by Rogin[1] revealed that "an early form of the rotary harrow, known as the Nishwitz harrow, aroused considerable interest soon after the Civil War." This harrow consisted of slightly concave disks mounted on separate standards to an A-shaped frame. The disks on each leg of the frame threw the soil outward. "It was apparently not until the late seventies, when the LaDow and the Randall disk harrows appeared, that this type of implement attained considerable vogue." Disk harrows were largely made in blacksmith shops up until about 1880, when the Keystone Manufacturing Company of Sterling, Illinois, started factory production. The cutaway disk was introduced in the early nineties.

The spring-tooth harrow was patented in 1877, and two factories started making them in 1878. Homemade types of peg-tooth or straight-tooth square and triangular harrows were mentioned as being used as early as 1790. The Soil Surgeon is a recent development and was introduced in the late 1940s.

Disk Harrows. Uses. The disk harrow is adapted to a wide variety of uses in many types of farming practices and management. Some of these uses are enumerated as follows:

1. It is used before plowing to cut up vegetable matter that may be on the surface, such as cornstalks, cotton stalks, and weeds, and to pulverize the top of the soil to such an extent that the furrow slices will make better connection with the bottom of the furrow soles, preventing air spaces when slices are turned. Disk harrows are frequently used in combination with crop-residue shredders to mix the shredded material into the soil.
2. It is used after plowing to pulverize the soil and put it in better tilth for the reception of the seed. Oftentimes, land plowed in the fall will need disking in the spring. This will save replowing and put the soil in the best possible condition for spring seeding.
3. It puts all plowed ground in condition for spring planting.
4. It is used for the cultivation of crops.
5. It is used for summer fallowing.
6. When seed are sown broadcast, it is used to cover them.

Types. Disk harrows are available in sizes suitable for any size tractor. There are many types of disk harrows, but they can be divided into two general classes, trailing and mounted.

Trailing Disk Harrows. Trailing disk harrows are hitched to the drawbar of the tractor and pulled by the tractor.

[1] Leo Rogin, *The Introduction of Farm Machinery*, University of California Press, Berkeley, Calif., 1931.

SINGLE-ACTION. Single-action trailing disk harrows consist of two gangs of disks placed end to end which throw the soil in opposite directions (Fig. 11-1). The cutting width for single-action disk harrows may range from 4 to 12 feet. Sizes wider than 12 feet have end sections that fold over on the main harrow so the harrow can pass through gates (Fig. 11-2).

DOUBLE-ACTION. The double-action disk harrow is often called a *tandem harrow* because a set of two gangs follows behind the front gangs and is

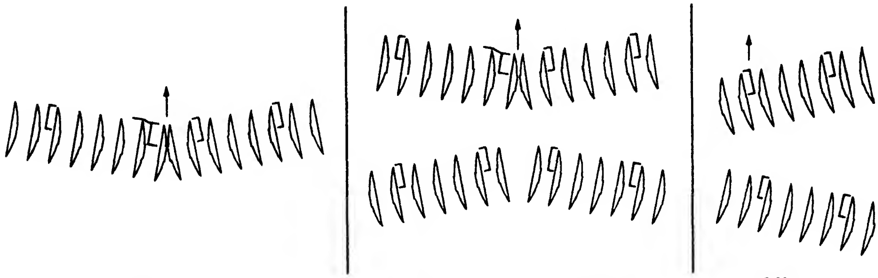

Fig. 11-1. Three types of disk harrows according to gang arrangement.

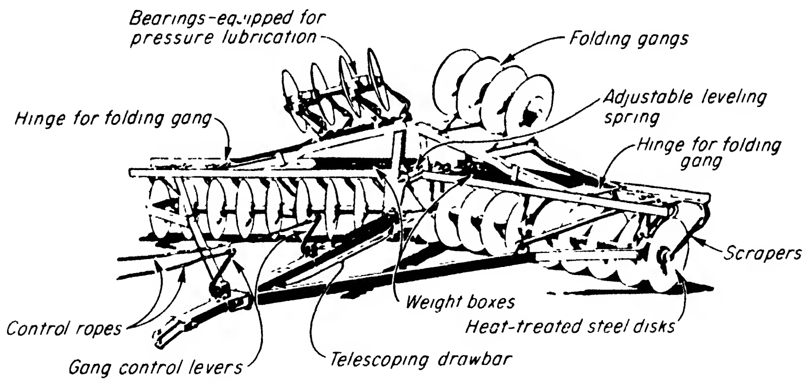

Fig. 11-2. Single-tractor disk harrow showing extension gangs folded. (*Deere & Co.*)

arranged so that the disks on the front gangs throw the soil in one direction (usually outward) and the disks on the rear gangs throw the soil in the opposite direction (Fig. 11-1). Generally, the trailing-type disk harrow cannot be lifted off the ground for turns, but the harrow shown in Fig. 11-3 is equipped with transport wheels and a remote-control hydraulic lift. The sizes in width of cut may range from 5 to 15 feet.

OFFSET. The offset disk harrow is given this name because the harrow can be operated in offset positions in relation to the tractor (Fig. 11-4).

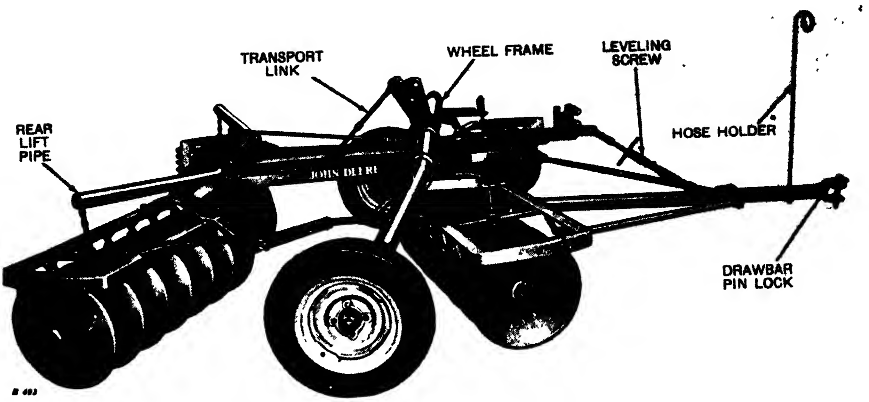

Fig. 11-3. Tandem disk harrow equipped with wheel carrier and hydraulic lift. (*Deere & Co.*)

A change in the hitch can cause the harrow to run to either the right or left of the tractor. Thus, it is possible to operate a harrow under limbs, near trees in an orchard, while the tractor runs out beyond the limbs. The offset disk harrow is becoming popular for straight-field disking, because the tandem-arranged gangs of disks give a double disking and leave the soil smoother than is usually obtained with a four-gang double-action harrow. Offset harrows are available in sizes ranging from 4½ to 30 feet. Rubber-tired transport wheels are available for many makes. These carrier wheels are used to transport the harrow to and from fields, across grass waterways, and may serve as depth gages. Figure 11-5 shows an offset disk harrow, with three gangs in a squadron arrangement. This arrangement of the gangs is suitable for disking on hilly or contoured land.

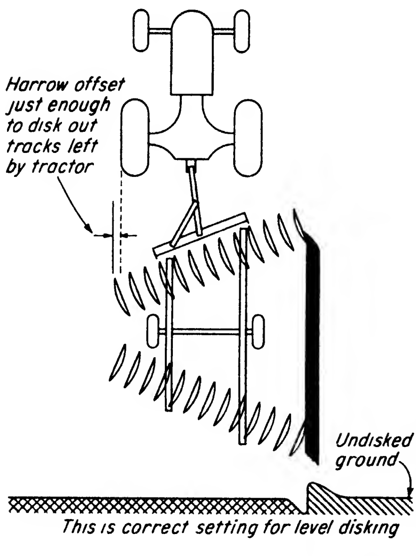

Fig. 11-4. Correct hitch for an offset disk harrow. (*J. I. Case Company.*)

SPECIAL TRAILING TYPES. Special heavy-duty disk harrows are built heavy enough to chop up brush on pasture lands and excessively heavy crop residues in sugar-cane fields. They are suitable for deeper harrow-

ing of heavy soils. One company lists a heavy-duty disk harrow as follows: width of cut 13 feet, twenty-four disks 28 inches in diameter, total weight 8,900 pounds, requiring a tractor having 110 to 130 drawbar horsepower.

Heavy-duty harrows are usually equipped with cutaway or notched-edge disk blades. They are available in both single- and double-action types. Figure 11-6 shows a heavy-duty disk harrow which is constructed

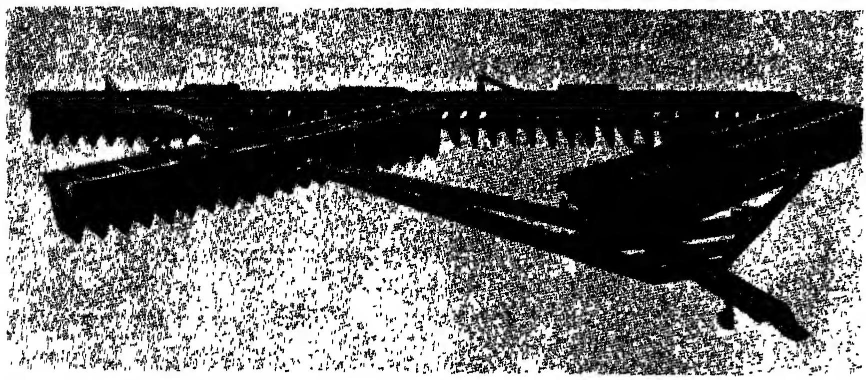

Fig. 11-5. Squadron hitch arrangement of offset disk-harrow gangs. (*Deere & Co.*)

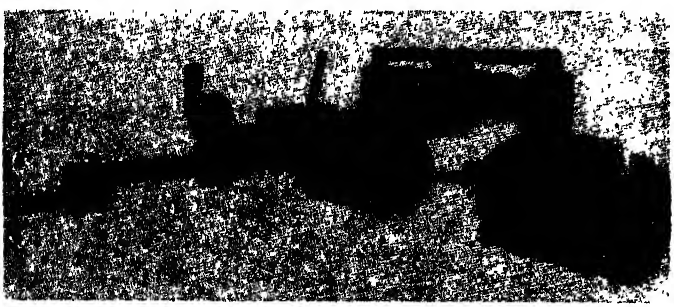

Fig. 11-6. Heavy-duty disk harrow constructed so the gangs are reversible and tiltable as well as angled for penetration. (*Rome Plow Company.*)

so that the gangs are both reversible and tiltable. This harrow is suitable for making wide beds, irrigation borders, or ditches.

Mounted Disk Harrows. This type of disk harrow is designed to be used with tractors equipped with three-point hitch and hydraulic lift systems. Different manufacturers have given the mounted disk harrow different names, such as *direct-connected, pickup,* and *lift-type.* As the mounted disk harrow is generally a unit assembly with fixed-angle construction, it can be lifted with hydraulic power lifts and backed into

corners, used close to fences and along ditches or borders. The hydraulic control permits adjustment of the disks to desired depths (Fig. 11-7).

SINGLE-ACTION. Most of the regular two-gang single-action mounted disk harrows are of the heavy-duty type.

DOUBLE-ACTION. The conventional four-gang tandem power-lifted disk harrow has a fixed-angle construction (Fig. 11-7). It is available in widths ranging from 5 to 6 feet. There is sufficient flexibility in the hitch not to interfere with the steering of the tractor.

OFFSET. The offset double-action mounted disk harrow consists of two gangs of disks arranged in a fixed-angle frame so that one gang runs behind the other (Fig. 11-4). The rear gang may be set to run directly behind the front gang, giving a double disking to the soil, or it can be adjusted sidewise to run in an offset position to the right or to the left as desired. Adjusting brackets are available for leveling the harrow sidewise and for increasing or decreasing pressure on either side of the harrow. The harrow can also be adjusted to regulate the penetration of the rear gang. Mounted offset harrows are available in widths ranging from 3¾ to 6¾ feet.

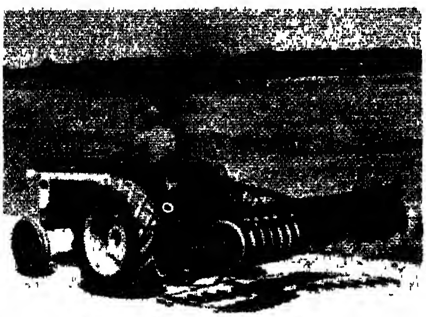

Fig. 11-7. Tandem double-action disk harrow. (*International Harvester Company.*)

Component Parts of Disk Harrows. A disk harrow consists of a number of units or component parts, such as the disks, disk gangs, frame, standards, bearings, bumpers, scrapers, weight boxes, and leveling devices.

Disks. Round, smooth-edged disks (Fig. 11-3) are used on most disk harrows. Special harrows are equipped with disks having a *cutaway*, *notched*, or *scalloped edge* (Fig. 11-6). Where there is much residue to be cut, cutaway disks are recommended for the front gangs and round disks for the rear gangs. Disk blades for harrows range from 16 to 28 inches in diameter. The 18- to 24-inch sizes are popular for regular farm use. Heavy-duty disk harrows are equipped with disks ranging from 26 to 28 inches in diameter. Disks for harrows are made of high-grade, heat-treated steel.

Disk Gangs. Gangs for disk harrows consist of three to thirteen disk blades assembled on a long *gang bolt*, or *arbor bolt*, which is generally square. The spacing between disks ranges from 6 to 9 inches for light-duty harrows and from 10 to 12½ inches for heavy-duty harrows. The disk blades are held an equal distance apart by a spool-shaped casting.

Harrow Frame. Each gang of disks has a strong rectangular or tubular

frame supported above the gang by standards that rest on axle bearings. The gang frames of a double-action harrow are connected by a linkage arrangement that, in most cases, permits adjustment of the angle of the

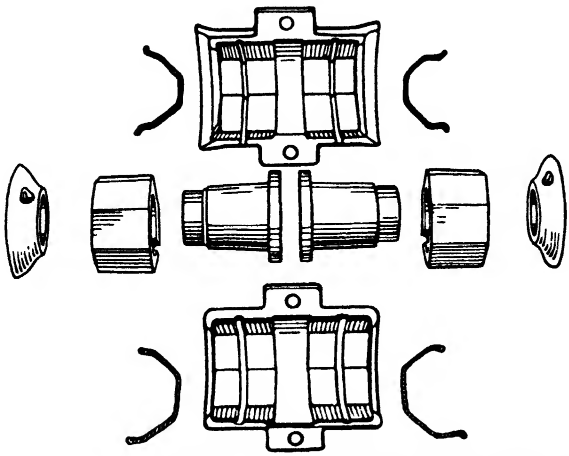

Fig. 11-8. The parts of a chilled-iron disk-harrow bearing.

gangs to obtain varying degrees of soil penetration. The pull or hitch bar is attached to the frames of the two front gangs. The unit-lift or pickup harrows may have a rigid frame construction to hold all gangs in a fixed position.

Bearings. Lightweight disk harrows generally have two bearings per gang, while heavy brush and bog harrows may have several bearings per gang. These bearings consist of a specially designed spacer spool around which is bolted a malleable cast-iron housing. The standards for the frame and the pull bars are attached to the bearing housing. A wood bushing can be used between the spool and the housing. The spool on many harrows is made of white, chilled cast iron and serves as the moving part of the bearing (Fig. 11-8). Some harrows are equipped with antifiiction bearings. These may have pressure lubrication fittings or may be seal-packed for their lifetime (Fig. 11-9).

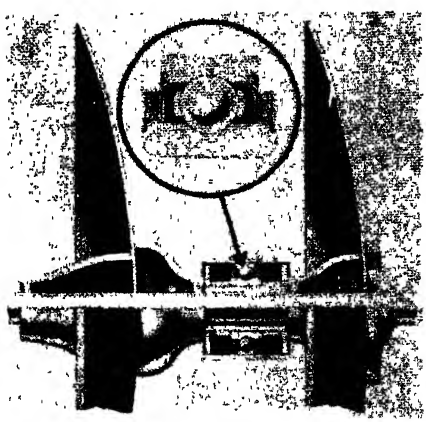

Fig. 11-9. A greased, packed. permanent-sealed antifriction bearing for disk harrow. (*Allis-Chalmers Mfg. Co.*)

Bumpers. Where two gangs of disks are set to throw the soil outward, as shown in Fig. 11-1, the sidewise forces acting on the disks as they are drawn forward tend to force the gangs toward each other. A half-moon-shaped cast-iron plate weighing several pounds is placed on the convex side of the disk at the end of the gang. Rather than absorb all the sidewise pressures in the frame, standards, and bearings, the gangs are allowed to bump together against the bumper plates. Bumper plates can be placed on the outer ends of the rear gangs of double-action disk harrows to prevent the head of the gang bolt hanging and snagging on posts and trees. The weight of the bumpers also aids in holding the gang level for uniform penetration from end to end of the gang.

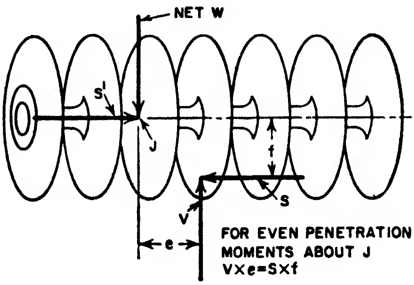

Fig. 11-10. Moments of forces affecting the even penetration of a regular disk-harrow gang. For even penetration the net *W* (total weight minus any upward pull) must act off center. The number of disks in the gang has no effect on the distance *e*. (*A. W. Clyde, University of Pennsylvania.*)

Scrapers. Scrapers are placed on the disk harrow to clean and remove soil that may stick to the concave side of the disk blades (Fig. 11-3).

Weight Boxes. A boxlike framework is often provided on the frame so that weights can be placed on the harrow gangs. In some cases, specially shaped iron weights can be attached to the harrow frame. Where the gangs are long, the weight should be added near the bumper end of the gang to offset the tendency for that end of the gang to be forced upward by the sidewise forces acting on the gang.

Leveling for Even Penetration. Clyde[2] analyzes the forces acting on a disk-harrow gang as follows:

> Figure 11-10 shows how forces S and V act on a gang as viewed from the rear. S is balanced by an equal side thrust, S′, applied either at the bumper or at the bearings. It is evident that the pair of forces, S and S′, tends to lift the bumper end and to force the other end down. To prevent that, the net weight on the gang must be offset from V. In practice this is done by applying most of the frame's weight near the bumper end. Sometimes the frame must borrow weight from the concave end of the gang (pull up on it) in order to hold down hard enough on the bumper end. Thus, there is a natural tendency for the bumper end of the gang to run shallow. Uneven penetration causes uneven wear of the disks.

[2] A. W. Clyde, Mechanics of Farm Machinery, *Farm Impl. News,* January–March, 1944.

In offset disk harrows the basic principle is that the side force against the front gang is opposed by the side force of the rear gang, these forces being out of line. To balance them, the pulling forces must be out of line with the backward forces on the gangs. Another method of getting the same results is to combine the backward and side forces into one force, *RH*, on each gang, as in Figure 11-11. The pull balances these two, hence they are placed with their arrows at their junction *H*, making the parallelogram, and get the diagram *PX*, which is the pull needed. *H* may be called the center of resistance in the same sense as used with the plow. The numbers in Figure 11-11 are shown for 22-inch disks and the angles are chosen so that the S of one gang equals the S of the other. This requires that the rear gang be angled more than the front, because the rear has less net weight acting on its disks.

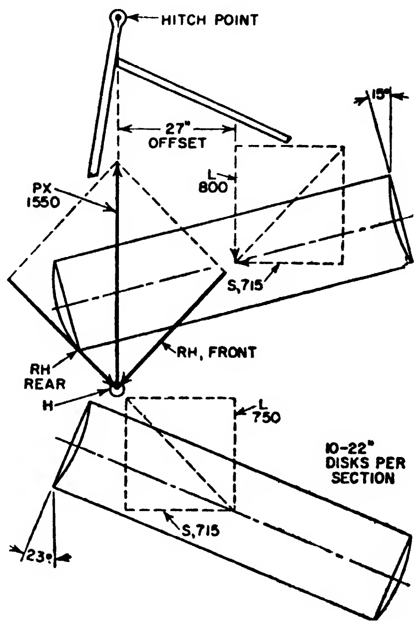

Fig. 11-11. Moment of forces acting on the gangs of an offset disk harrow. (*A. W Clyde, University of Pennsylvania.*)

Leveling devices to give even penetration of gangs on double-action disk harrows may consist of *tension springs, turnbuckles, snubber blocks,* and *hold-down bars.*

Soil Penetration of Disk Harrows. There are many factors within the harrow itself that will influence the depth to which it will penetrate the soil. They are enumerated as follows:

1. The angle of the disk gang
2. The weight of the harrow
3. The sharpness of the disks on the gangs
4. The size of the disks
5. The concavity of the disks
6. The angle of the hitch

All these factors are incorporated within the harrow itself. Other factors, however, that influence the depth of penetration have nothing to do with the harrow, such as the condition of the soil, the amount of moisture, whether plowed land or unplowed land, the amount of trash

on the soil, and the amount of organic matter that may be in the soil.

Power Angling of Harrow Gangs. Most trailing, double-action, and offset disk harrows are equipped with remote-control double-action hydraulic cylinders (Fig. 11-3). The hydraulic cylinder is used both to angle the gangs for operation and to straighten the gangs for turns, crossing of grassways in fields, and transportation.

Draft of Disk Harrows. Richey[3] gives the draft and power requirements of a single-action disk harrow as 40 to 130 pounds per foot of width and a double-action tandem disk harrow as 80 to 160 pounds per foot of width. The draft of a double-action harrow equipped with 22-inch disks and spaced 9 inches was given as ranging from 170 to 225 pounds per foot of width or 90 per cent of the weight of the harrow.

Tests conducted by Promersberger and Pratt[4] with a tandem disk harrow cutting a depth of 2 to 3 inches in loam and clay fallow soils gave a draft of 57 to 150 pounds per foot of width. The average horsepower-hours per acre was 1.2 to 3.3. When the harrow was operated at a depth of 4 to 6 inches, the draft per foot of width ranged from 148 to 182 pounds. The average horsepower-hours per acre was 3.3 to 4.0. An offset orchard harrow cutting a depth of 5 to 7 inches gave a draft of 195 to 258 pounds per foot of width. The average horsepower-hours per acre was 4.3 to 5.7. The draft increased as the depth was increased.

Spike-tooth Harrows. A typical spike-tooth harrow is shown in Fig. 11-12. It is commonly called a spike-tooth harrow because the teeth that stir the soil resemble long spikes. This harrow is also known as a *peg-tooth harrow*, a *drag harrow*, a *section harrow*, or a *smoothing harrow*. Its principal use is to smooth and level the soil directly after plowing. It will stir the soil to a depth of about 2 inches if weighted. It can be used to cultivate corn and cotton and other row crops in early stages of growth.

The sections may range in width from 4 to 6 feet and may have twenty-five, thirty, or thirty-five teeth. Several sections can be attached to a hitch bar and a wide swath harrowed. The sections may be either rigid or flexible.

Sections that have guard rails across the ends of the bars are called closed-end harrows, while those that do not have guard rails are called open-end harrows.

Spring-tooth Harrows. Trailing spring-tooth harrows are made in sections somewhat like spike-tooth harrows. The sections vary in width from 3 to 5⅔ feet. The sections may have from eight to twelve teeth. A single section may be used alone, or several sections may be hitched together

[3] American Society of Agricultural Engineers Data: Crop Machines Use; I. Draft and Power Requirements of Crop Machines, *Agr. Engin. Yearbook*, p. 69, 1954.

[4] W. J. Promersberger and G. L. Pratt, Power Requirements of Tillage Implements, *N. Dak. Agr. Expt. Sta. Bul.* 415, 1958.

and used as a unit. The number of sections used together will depend upon the power available.

Tractor-mounted types of spring-tooth harrows are available in assembly units that can be lifted with hydraulic power (Fig. 11-13).

Spring-tooth harrows are adapted for use in rough and stony ground. They are also used extensively to loosen previously plowed soil ahead of a grain drill seeding rice or small grains. The teeth will penetrate deeper than those on spike-tooth harrows, and they will give when obstructions are struck. The spring-tooth harrow is frequently advertised as a *quack-*

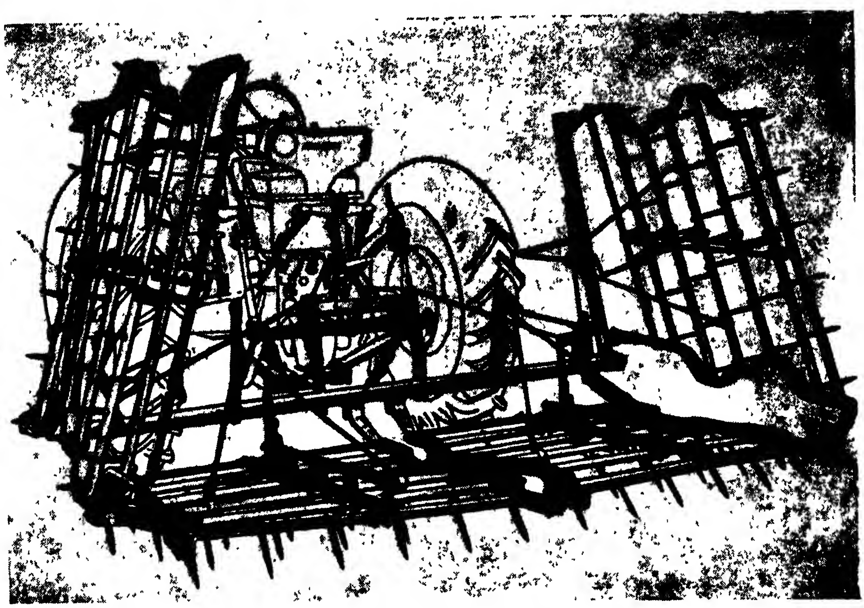

Fig. 11-12. Spike-tooth harrows: four-section tractor-pickup closed-end type with two outer sections folded. (*Deere & Co.*)

grass and *Bermuda-grass eradicator*, since the teeth penetrate deeply and tear out the roots and bring them to the surface. Alfalfa sod is also cultivated with spring-tooth harrows. The teeth consist of wide, flat, curved, oil-tempered bars of spring steel, one end of which is fastened rigidly to a bar; the other end is pointed to give good penetration. The depth to which the teeth will penetrate the soil is controlled by adjusting the angle of the teeth by means of levers, as in the case of the spike-tooth harrow. Some spring-tooth harrows are provided with a power-angling hitch.

Harrow teeth for spring-tooth harrows are available with points of various widths and shapes and with detachable points for different type.

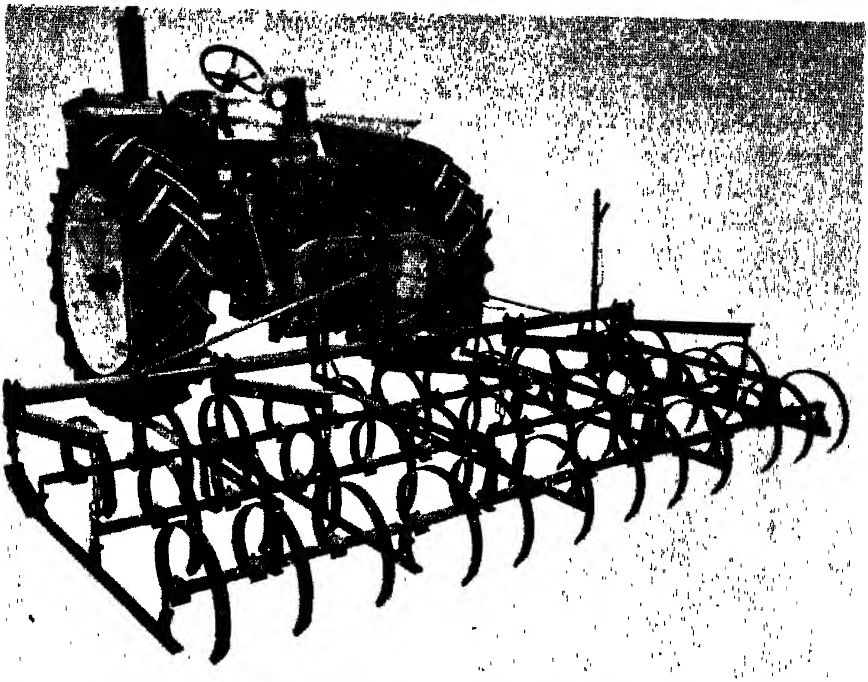

Fig. 11-13. Tractor-mounted hydraulically lifted spring-tooth harrow. (*Deere & Co.*)

of work (Fig. 11-14). A rake-bar smoothing attachment is available, if desired, for smoothing the soil behind the spring-tooth harrow. The draft of a spring-tooth harrow may range from 75 to 150 pounds per foot of width, depending upon the type work and soil conditions.

A *B* *C* *D*

Fig. 11-14. Types of teeth on spring-tooth harrows: *A*, regular; *B*, quack grass; *C*, alfalfa; *D*, detachable point.

Special Hitches. Units are available for four or more sections of trailing spike- and spring-tooth harrows.

Special Harrows. Harrows that act on the soil in a special manner are the weeder-mulcher and the Soil Surgeon.

Weeder-Mulcher. Weeders are excellent tools for making a mulch, for breaking the soil crust over germinating seeds, and for controlling and destroying young weeds just after the field-crop plants have begun to grow. Figure 11-15 shows a weeder-mulcher.

Soil Surgeon. The Soil Surgeon has a series of U-shaped swiveling knives under a steel plate.

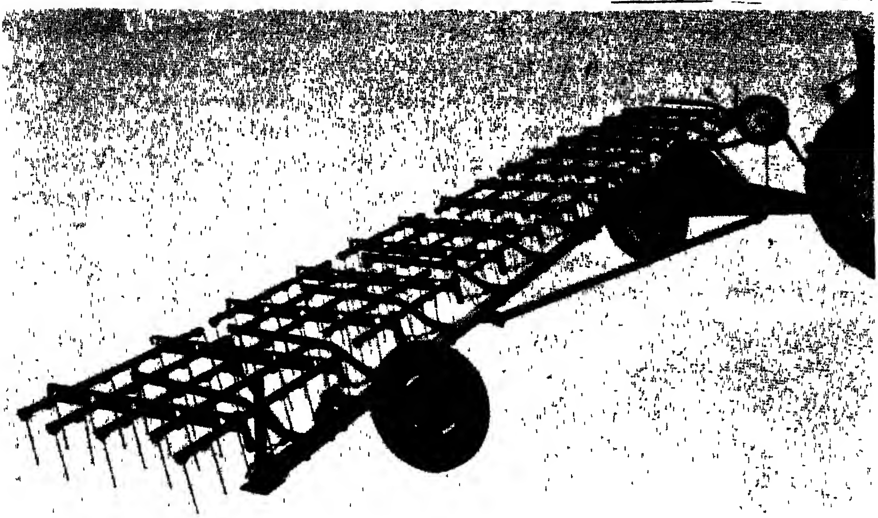

Fig. 11-15. Weeder-mulcher that covers a strip 37 feet wide. (*Deere & Co.*)

LAND ROLLERS AND PULVERIZERS

Land rollers or pulverizers are tools used for the further preparation of the seedbed. They can be divided into two classes according to the kind of work they do, the *surface packer* and the *subsurface packer*.

Surface Packers. There are several different kinds of commercial surface packers and pulverizers, named according to the shape of the roller surface: the V-shaped roller-pulverizer, the combination T-shaped and sprocket-wheel pulverizer, and the flexible sprocket-wheel pulverizer. The subsurface packers consist of a V-shaped packer and the crowfoot packer.

The surface roller is coming into more general use each year because it has a varied number of uses. The most important is as a clod crusher; at this it has no equal. Another very important use is to finish preparing the seedbed by thoroughly pulverizing and firming the loose soil so that there will not be any large air spaces or pockets. It presses the upper soil down against the subsoil, making a continuous seedbed in which moisture is conserved and given to the roots of the plants as it is needed. Also, when meadow, wheatland, and pasture land have heaved badly from freezing, the land roller is good to press the soil back down around the roots.

V-shaped Roller-Pulverizer. The machine shown in Fig. 11-16 is a roller-pulverizer constructed of a number of wheel sections, so that when they are strung on a shaft the surfaces of the rollers form a kind of corrugation. It is from the shape of the surface it leaves that it gets the name

corrugated roller. Each wheel or section is about 5 or 6 inches thick and varies in diameter from 10 to 18 inches. The roller is hollow. It may consist of one or two pieces and is cast out of semisteel. When placed upon a shaft and rolled across the soil, it leaves small ridges. If only one set of rollers is used, these ridges will be rather large, being 5 or 6 inches from one crown to the other. The common method, however, is to use a rear set of rollers so arranged that they will split the ridge made by the front pair, leaving a number of very fine ridges. It is claimed that this type of roller to a certain extent will prevent wind erosion. It also rolls,

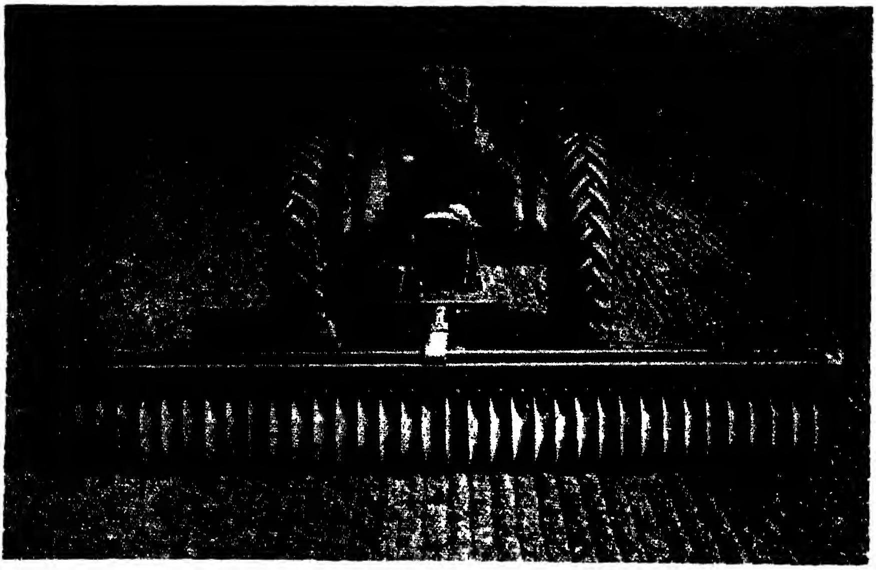

Fig. 11-16. Rear view of land roller with V-shaped iron wheels. (*Brillion Iron Works, Inc.*)

pulverizes, packs, levels, cultivates, and mulches the soil in one operation. Figure 11-17 shows a roller-pulverizer spring-tooth harrow combination. The front and rear roller gangs are spaced a few feet apart, and spring-harrow teeth are mounted between the sections to harrow the soil and bring clods to the surface so they can be crushed by the rear roller gang. Figure 11-18 shows a land roller equipped with a seeding attachment.

Combination T-shaped and Sprocket-wheel Pulverizer. This type of roller-pulverizer has alternate T-shaped and sprocket-wheel sections assembled on a shaft (Fig. 11-19). T-shaped wheels crush and pulverize the soil, while the sprocketlike wheels give a mulching effect, leaving loose pulverized soil on the surface.

Treader Packer. The packer shown in Figure 11-20 is what might be called a heavy-duty rotary hoe or skew packer. The packer wheels have

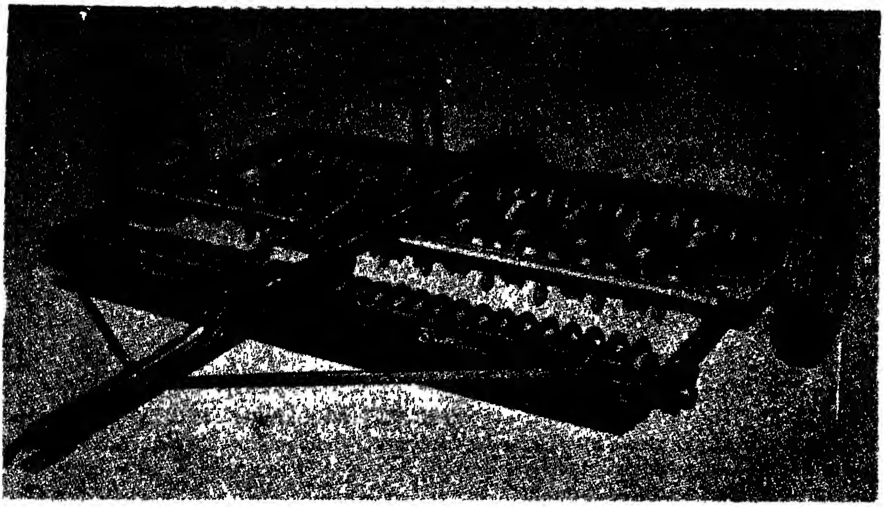

Fig. 11-17. Combination land roller and spring-tooth harrow. (*Brillion Iron Works, Inc.*)

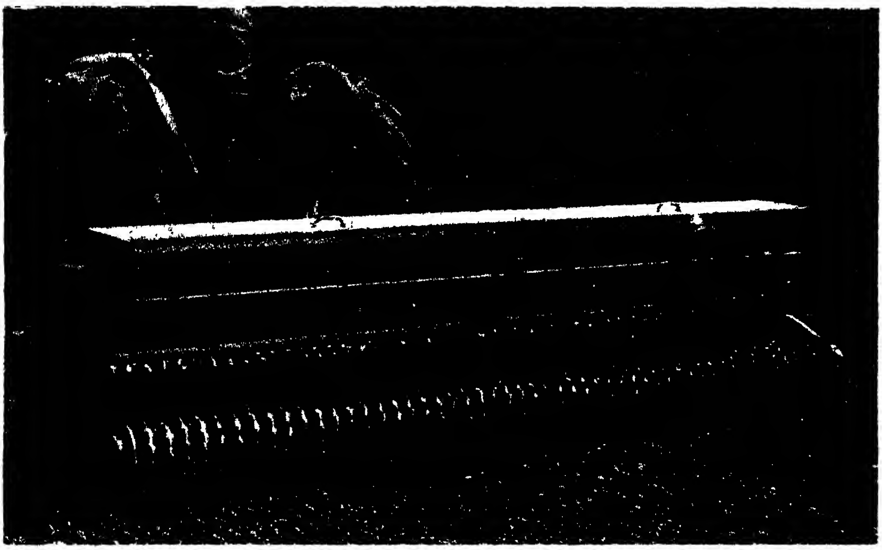

Fig. 11-18 Land roller equipped with seeding attachment. (*Brillion Iron Works, Inc.*)

heavy curved teeth that will penetrate the soil when the machine is operated with the points run forward. It serves as a packer or treader when operated with points run so that the rounded or back part of the points strike the soil first. When the wheels are run backward, they serve as packers and, if used on wheat stubble, will tread part of the straw into the soil. When the wheels are run forward, they will break up and pul-

verize soil and uproot weeds. The two gangs of rotary hoelike wheels are operated at an angle like an offset disk harrow (Fig. 11-20).

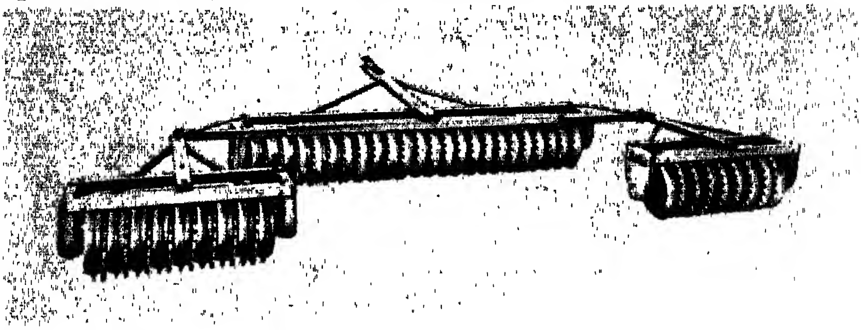

Fig. 11-19. Squadron hitch arrangement for land roller that has alternate T-shaped rollers and sprocket-wheel-type crushers. (*Brillion Iron Works, Inc.*)

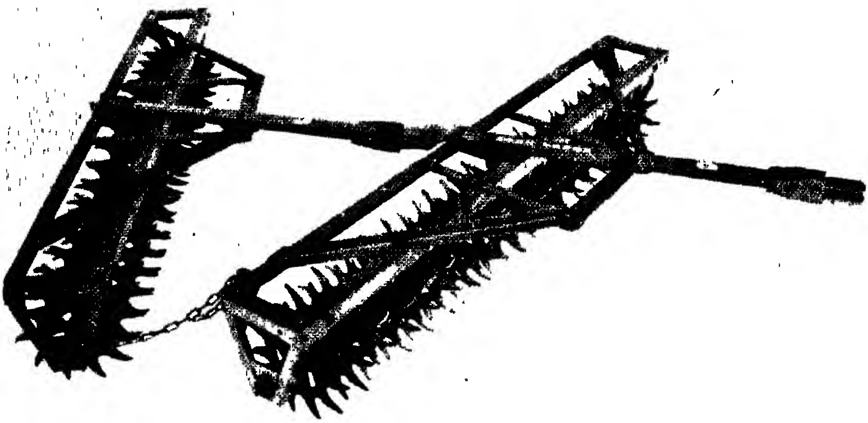

Fig. 11-20. Treader-packer composed of two gangs of heavy rotary hoes set at an angle like an offset disk harrow. (*Deere & Co.*)

Homemade Rollers. Many farmers do not care to go to the expense of buying a commercial type of land roller and will make one to serve the purpose from material that can be had on the farm. The principal types of homemade land rollers are the log roller and concrete rollers.

Log Roller. The log roller is a common homemade type found on the farm. It consists of a round, smooth log with two spikes placed in the ends and a frame built to provide a means of attaching the tongue and eveners. Log rollers should not be very long, because, when turning, if a wide circle is not made, one end will remain stationary while the other is pulled around. The result of turning in this manner will be a tendency to dig holes with one end of the roller. It is better, therefore, to use short

sections and hinge them together with a knuckle joint of some kind. Such an arrangement will allow easier turning.

Subsurface Packer Rollers. It is often desirable to pack the subsurface of the soil. Special tools for doing this are called *subsurface packers.* One common type resembles closely the culti-packer. It consists of a number of wheels with V-shaped rims strung on an axle with the frame overhead in the same manner as the culti-packer, but instead of the rims of the wheels setting close together, there is an interval of several inches between them (Fig. 11-21). The rims of these wheels are also rather narrow. Their V shape allows them to go below the surface, pressing the soil together and leaving a good mulch on top. Another roller which can be classed as a subsurface packer is shown in Fig. 11-22. Because of the

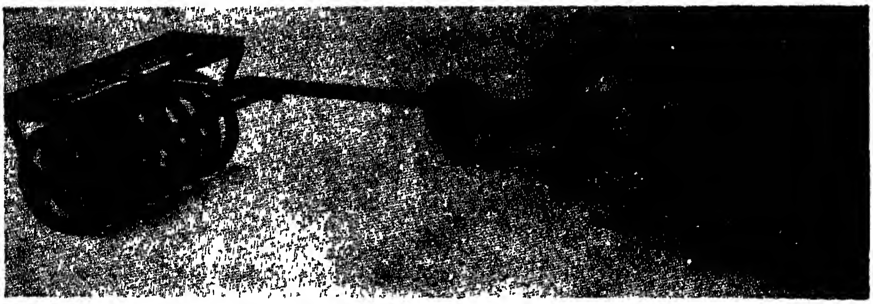

Fig. 11-21. A packer attachment, equipped with V-shaped wheel rims, that is used with a trailing plow. (*International Harvester Company.*)

shape of the packer wheel rims it is called a crowfoot packer. The results of conserving moisture by subsurface packing are shown in Table 11-1. These packers can be obtained in regular units or as attachments for plows.

Drags. In the preparation of a good seedbed, excellent work can be done by the use of ordinary drags which will crush clods, level the land, and firm the soil around the seed. In many cases the drag can be made to take the place of the roller. There are no commercial types of drags, but any farmer can build an ordinary homemade drag that will serve his purpose. The most common drag is the *plank,* which consists of a number of 2 by 8s, 2 by 10s, or any convenient size of plank lapped upon one another and firmly fastened by cross sills. Many other types of homemade drags too numerous to mention can be made.

SUBSURFACE TILLAGE TOOLS AND FIELD CULTIVATORS

The need for control of wind and water erosion and for the conservation of moisture in the Great Plains region of the Middle West has

brought about the development of new farming practices and new farm tools. The objective is to till the soil in such a manner that the crop residue will be left on the surface. This method of farming is known by several different names, such as *plowless farming, trash farming, stubble mulch, residue management, subsurface tillage,* and *minimum tillage.* In the opinion of the author, subsurface tillage appears to be the most

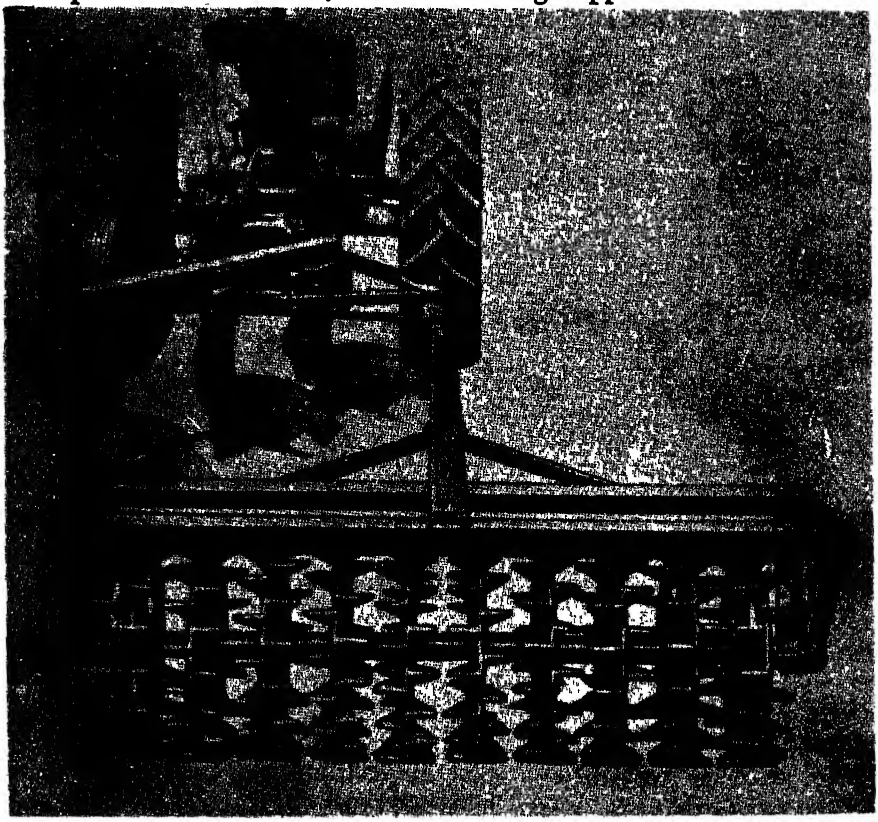

Fig. 11-22. A subsurface crowfoot packer being used behind a three-bottom moldboard plow. (*Brillion Iron Works, Inc.*)

appropriate name, as all the tools used in the operations stir and till the soil beneath the surface and under the trash.

The advantages listed for this method of farming are:

1. Increase in the capacity of the soil to absorb water
2. Reduction of runoff
3. Reduction of water and wind erosion
4. Reduction of rate of surface evaporation
5. Reduction of crop cultivation to kill weeds

On the other hand, many farmers say that the stubble mulch is hard to handle because it makes it difficult to destroy undesirable vegetation, to develop a good seedbed, and to plant, and under some conditions it increases operation costs. Subsurface tillage requires considerable know-how and skill in operation of the tools used. Certain areas and soils are definitely not suited to this system of farming. For example, in the more moist areas, there is the danger of increased insect population.

TABLE 11-1. SOIL MOISTURE CONTENT IN ACRE-INCHES TO A DEPTH OF 4 FEET IN THE SPRING OF THE CROP YEAR AFTER THE FALLOW PERIOD, OF FALLOW PLOWED ON THREE SPRING DATES, WITH AND WITHOUT SUBSEQUENT SUBSURFACE PACKING, ADAMS BRANCH EXPERIMENT STATION, LIND, WASHINGTON

Tillage treatment	Soil moisture, acre-inches								Relative amount of conserved moisture
	1918	1919	1920	1921	1922	1923	Average	Conserved moisture*	
Early spring plowing:									
Packed	4 91	5.72	5 20	6 03	5.93	5 26	5.51	3 43	101
Not packed	4 95	6.22	4.94	5.29	6 01	5.45	5 48	3.40	100
Intermediate spring plowing:									
Packed	5 06	5 89	5.33	5 93	5 71	5 31	5 54	3 46	102
Not packed	4 67	5.91	5 16	5 50	5 86	5 75	5 47	3 39	100
Late spring plowing:									
Packed	4.71	6.28	5 26	5 44	5 46	5 26	5 40	3 32	98
Not packed	5.09	6 40	5 06	5 28	5 65	5.22	5 45	3 37	99

NOTE. All plots were disked at the early spring date and plowed as indicated. The packed plots were packed with a Campbell subsurface packer weighted to 30 pounds per wheel. All were immediately cultivated with a spring-tooth harrow. Subsequent tillage was given as necessary for weed control.

* Residual moisture to a depth of 4 feet, 2.08 inches, 4-year average.

SOURCE: *Wash. Agr. Expt. Sta. Bul.* 183, 1924.

Implements that operate under and do not materially disturb the trash on or near the surface are the most effective for subsurface tillage. The tools that meet these requirements are *sweeps* and *rod weeders*.

Subsurface Tillage Sweeps. To work under trash, sweeps must be set almost flat, mounted on strong narrow standards that are staggered on the frame far enough apart to permit trash to flow around and between the standards. The complete tool is frequently called a *field cultivator* (Fig. 11-23). Tractor-drawn machines with subsurface tillage gangs and sweeps are provided with depth regulators and power lift and can be obtained in widths ranging from 5½ to 15 feet, depending on type of work to be done.

Where the tool is used for summer fallowing, the spring teeth have 6-inch spacings while the stiff standards have a 9-inch spacing. If row crops are to be cultivated, the standards can be spaced to suit the row width. Trash must not be allowed to collect on the standards, to drag, or to cover small plants. To prevent this, large 16- to 22-inch sweeps are used in connection with notched-edge rolling colters and concave disk hillers. To prevent covering small plants, large rolling colters are used on each side of the rows to serve as fenders or shields.

Subsurface Tillage Rod Weeders. Rod weeders are used extensively throughout the wheat-growing region of the Great Plains of the United

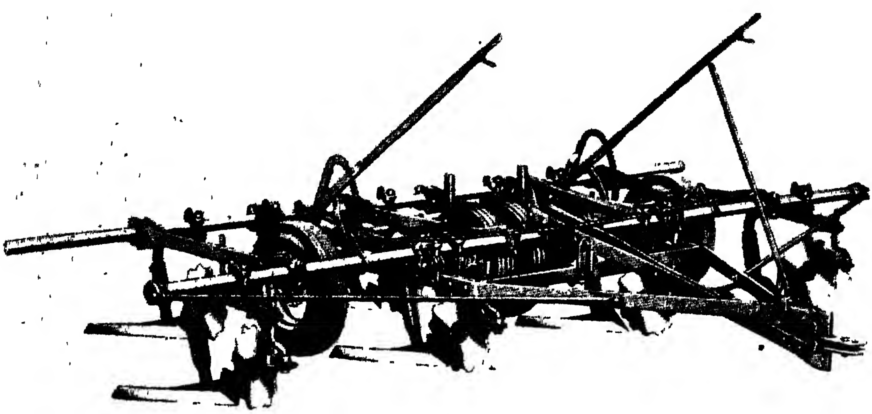

Fig. 11-23. Tool carrier equipped with wide subsurface sweeps. Units from 8 to 37 feet in width can be obtained. (*Deere & Co.*)

States and Canada. They are used almost exclusively for controlling weed and voluntary vegetative growth on lands where summer fallowing is practiced.

The average rod weeder consists of a sturdy frame with four to five plowlike beams which have a shoe or slip nose on each point. Extending through a bearing in the shoes are round or square high-carbon-steel rods that revolve slowly. The rods are driven by a combination of sprocket chain and gear drive from one wheel. A lever or screw-type depth regulator is provided. The wheels on each end vary in diameter from 18 to 38 inches, depending on the width of the machine. The rod drive wheel is provided with lugs. The width of single units ranges from 8 to 12 feet, duplex units 18 to 24 feet, and triplex units 36 feet. In operation, the revolving rod runs a few inches beneath the surface, pulling up and destroying all vegetative growth. The rod revolves to prevent the roots of plants from hanging onto it. The front side of the rod moves upward

to pull up and shed the roots of plants. Therefore, a reversing drive is provided.

Some farmers have substituted a sharp, heavy blade for the rod. This blade, fastened to middlebreaker beams, may be 8 to 10 feet in length. It is also provided with an angling device for suction and penetration.

Rod-weeder attachments are available for chisel-type plows.

ROTARY HOE

When there is a large amount of crop residue on the surface in a fluffy condition, the rotary hoe, operated in reverse, is useful in packing the residue down into the surface soil. This treatment makes the use of field cultivators and rod weeders easier. See Chap. 13 for additional uses of the rotary hoe.

Table 11-2 shows the corn yields for eight methods of seedbed preparation for corn, where crop residues were used as a mulch.

TABLE 11-2. 1949 CORN YIELDS FOR EIGHT METHODS OF SEEDBED PREPARATION FOR CORN

Treatment prior to planting			Yield, bushels per acre	
Residue location	Depth of tillage, in.	Implement used	Noble Co.* Miami silt loam	Throckmorton farm & Carrington silt loam†
Left on surface	6 to 7	Lister bottom and spring-tooth cultivator in strip only	99	64
Left on surface	3	Sweeps	78	64
Left on surface	3 & 7	Sweeps	76	59
Mixed 0 to 3 in.	3	Disk harrow	86	74
Mixed 0 to 6 in.	6	Cover crop disk	79	79
Mixed 0 to 3 in.	7	Special plow and disk	103	72
Under 4 in. to 7 in.	7	Ordinary plow	108	76
Mixed 0 to 3 in.	7	Ordinary‡ plow, special plow and disk	98	84

* Lowest significant difference, 5 per cent, Noble County, 17.4 bushels.

† Lowest significant difference, 5 per cent, Throckmorton Farm, 14.5 bushels.

‡ Ordinary plow in fall 1½ inches deep. Special plow in spring to mix the residue, 0 to 3 inches with 7-inch depth tillage.

SOURCE: E. R. Baugh et al., *Agr. Engin.*, 31(8):398–400, 1950.

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PROBLEMS

1. Define and give the objectives of secondary tillage.
2. List the equipment used for secondary tillage.
3. Give the various uses of disk harrows, and make an outline listing the various types of disk harrows.
4. Explain the different structural and design features of trailing single-action, double-action, and offset disk harrows.
5. Compare the advantages of the wheel-lift trailing disk harrow and the tractor-mounted power-lifted disk harrow.
6. Explain how the various forces acting on a disk harrow gang can be balanced to obtain even penetration.
7. Explain the various uses of spike-tooth and spring-tooth harrows.
8. Explain the uses of the various types of land rollers and pulverizers.
9. Discuss the advantages of subsurface or stubble-mulch tillage, and describe the equipment used.

PLANTING EQUIPMENT

12

The art of placing seed in the soil to obtain good germination and stands without having to replant is the goal of all who grow crops. There are a number of factors that influence the germination of seeds and the emergence of seedling plants. These are:

Quantity of seed planted
Viability of the seed
Treatment of the seed with chemicals to kill soil microorganisms
Uniformity of seed size
Planting depth
Type of soil
Moisture content of the soil
Type of seed-dropping mechanism
Uniformity of distribution of the seed
Type of furrow opener
Prevention of loose soil getting under the seed
Uniformity of coverage
Type of covering device
Degree of pressing and firming of the soil around the seed
Cleanliness and condition of the seedbed
Time of planting in relation to season
Temperature of the soil
Type of drainage
Condition of soil crusts
The good judgment, skill, and attention of the operator

History of Planter Development. Broadcasting seed over the broken soil and covering them with some type of harrow was the common method

of planting until about 1840. William T. Pennock of East Marlboro, Pennsylvania, was the first to start manufacturing grain drills,[1] although the first patent was granted to Eliakim in 1799.[2] The United States Census Report of 1880 estimated that about 53 per cent of the wheat sown in 1879 was planted with grain drills.

The earliest type of row-crop planter was perhaps a wooden keg with holes around the center to permit seeds to drop out. A patent was granted to D. S. Rockwell in 1839 on a device for the planting of corn. About 1892, the Dooley brothers of Moline, Illinois, developed the edge-selection drop for corn planters. The check-row planter was patented by M. Robbins of Cincinnati, Ohio, in 1857.

The Dow Law cotton planter was developed about 1870.[3] The cell-drop and picker-wheel planting mechanisms for cotton planters were developed in the 1880s. The hill-drop attachment did not come into use until the 1920s. See Appendix Table 7 for dates of planter development.

Classification of Planting Equipment. Planting equipment is here considered to be any power-operated device used to place seed, seed pieces, or plant parts in or on the soil for propagation and production of food, fiber, and feed crops. It is classified as follows:

- Row-crop planters
  - Trailing
    - Drill
    - Hill-drop
    - Check-row
  - Front tractor-mounted
    - Drill
    - Hill-drop
    - Check-row
  - Rear tractor-mounted
    - Drill
    - Hill-drop
    - Check-row
    - Transplanters or plant setters
- Broadcast-crop planters
  - Endgate seeders
  - Narrow- and wide-track and weeder-mulcher
  - Airplanes
- Grain drills
- Planting attachments for other equipment

[1] Leo Rogin, *The Introduction of Farm Machinery*, University of California Press, Berkeley, Calif., 1931.

[2] J. B. Davidson and L. W. Chase, *Farm Machinery and Farm Motors*, Orange Judd Publishing Co., Inc., New York, 1912.

[3] H. P. Smith and M. H. Byrom, *Tex. Agr. Expt. Sta. Bul.* 526, 1936.

ROW-CROP PLANTERS

Planters designed and constructed to plant seeds in rows far enough apart to permit cultivation of the crop are termed *row-crop planters.* Many row-crop planters are designed to plant seeds of only one certain crop, while others can be adapted to plant more than one crop by interchangeable hoppers, agitators, plates, and the speed-control mechanism of the seed metering parts. Generally, row-crop planters can be divided into five classes, named according to the kind of crop the planter is especially designed to plant. The classes are corn; cotton; sorghum; vegetable, beet, and bean; and potato.

Equipment for placing growing plants or plant parts in the soil is called a *transplanter.*

Corn Planters. Corn planters are used in almost every state of the United States, the southern provinces of Canada, and all countries where corn is produced in sizable quantities. In the United States, they are used most extensively in the Corn Belt of the north Middle West region.

Trailing and tractor-mounted corn planters can be classified according to the manner in which the seed are dropped: *drill, hill-drop,* and *check-row. Lister planters* are drill planters designed to plant corn in listed furrows.

Trailing Drill Planters. Trailing drill corn planters are available in two-, four-, six-, and eight-row units. Where the contour of the land and soil conditions permit, there is a tendency toward the use of the larger multiple-row flexible units. It reduces acre man- and tractor-power hours and reduces costs (Fig. 12-1). The drill planter is not equipped with the parts needed for checking. There is some tendency toward the increased use of drill planters for corn because, when corn is harvested with the mechanical corn picker, drilled corn gives a more even flow of corn through the picker mechanism and there are no distinct shocks to the picker, as is the case when harvesting hills of corn spaced 38 to 42 inches apart.

Trailing Hill-drop Planter. This type of corn planter is constructed similarly to the check-row planter described below. It has valves in the boot to collect the seeds and drop them in hills at regular intervals along the row. No wire is used; consequently, the hills in one set of rows will not be in line across the rows. The valves can be locked open, and the planter used as a drill planter.

Trailing Check-row Planters. The check-row planter (Fig. 12-2) is equipped with valves, checkheads, and wire to permit the operator to drop hills of corn in checks or squares so that cultivation can be made both with the rows and across the rows.

Some four-row trailing-tractor check-row corn planters appear to be

Fig. 12-1. Trailing eight-row flexible unit corn planter equipped with fertilizer hoppers (partially hidden by man), fungicide and herbicide hoppers and applicators, and large zero-pressure press wheels. Each unit follows the contour of the ground. (*Deere & Co.*)

two regular two-row planters coupled together with a suitable tractor hitch. Checkheads are provided only on the outer sides.

The valves can be locked open, and the planter used to drill the kernels of corn along the row. On some types of planters the valves can be power-operated without the wire and the kernels of corn dropped in hills or hill-dropped.

The sequence of operations for the various parts of a trailing check-row planter is as follows: traction power is furnished by the wheels. The

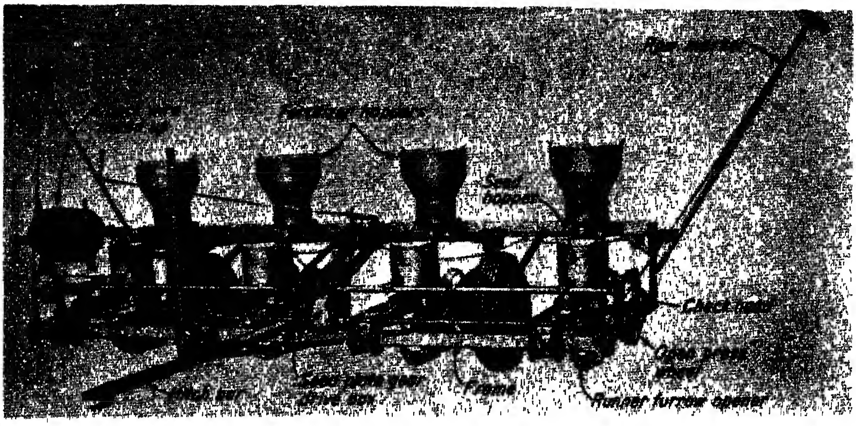


Fig. 12-2. Trailing four-row check-row corn planter with fertilizer attachment and mechanical power lift. (*Oliver Corp.*)

wheel turns the axle from which the power is transmitted to the feed shaft by sprockets and chains. The sprocket on the feed shaft works in conjunction with a clutch which permits the feed shaft to be revolved intermittently in order to turn the seed plates sufficiently to collect two or three kernels of corn on the top valve of the boot. As the planter moves forward across the field, buttons on a wire trip the top and bottom valves located in the boot, thus dropping the kernels of corn into the soil (Fig. 12-3).

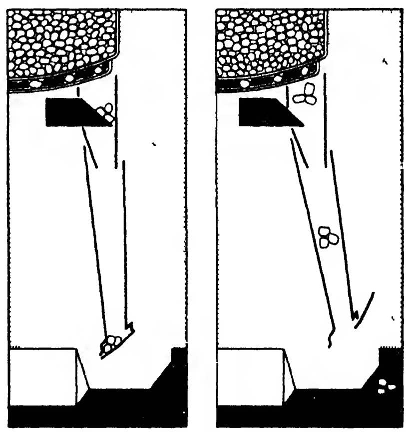


Fig. 12-3. Cross-sectional views of the action of the valves in a check-row planter boot: *left,* clusters of corn kernels are collected on the valves; *right,* the valves are open, and the lower cluster of kernels are deposited in the furrow. The valves will close and catch the clusters in passage. The valves can be locked open for hill-dropping or drilling.

Operating Check-row Planters. In the operation of tractor check-row planters, two types of check-wire anchor stakes are used, namely, the *tension-meter* type and the *pay-out* type (Fig. 12-4). When the tension-meter check-wire anchor stake is used with a two-row tractor planter, the stake is set directly behind the furrow opener or seedbox next to the wire side of the planter (Fig. 12-5). When the tension-meter stake is used with a four-row tractor planter, the anchor stake is set directly

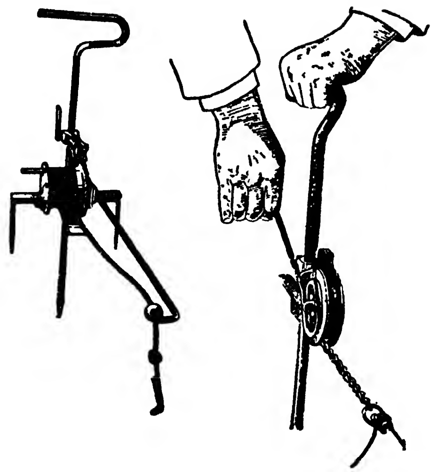


Fig. 12-4. Anchor stakes used with tractor check-row planters: *left,* pay-out type; *right,* tension-meter type.

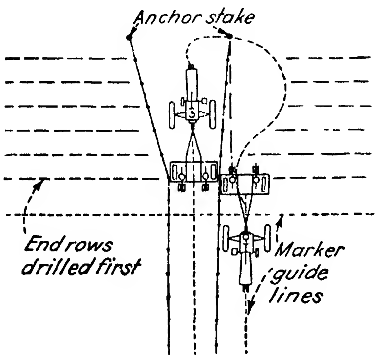


Fig. 12-5. Method of turning a two-row tractor check-row planter and location of tension-meter stake on driving up to and away from the stake. (*Deere & Co.*)

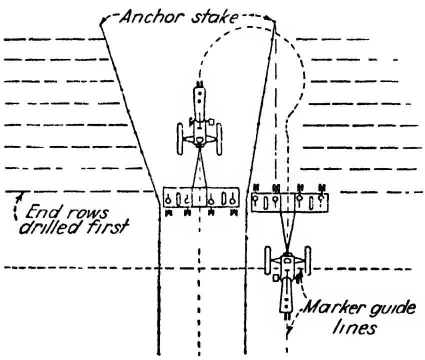


Fig 12-6. Method of turning a four-row tractor check-row planter and location of tension-meter stake on driving up to and away from the stake. (*Deere & Co.*)

behind the second furrow opener or seedbox from the wire side of the planter (Fig. 12-6).

When the pay-out check-wire anchor stake is used, it is set in line with the checkhead on the wire side of the planter. When the planter approaches the stake and is about eight buttons from it, the angle of the wire swings the ratchet on the stake out of engagement and permits the rope on the drum to pay out, thereby relieving the tension on the wire.

The tension meter is used to get a uniform tension on the wire each time the stake is set. An automatic wire release (Fig. 12-7) releases the wire when the planter approaches and is about seven buttons from the stake (Figs. 12-5 and 12-6).

The Check Wire. The check wire is usually furnished in 80-rod lengths, having buttons anywhere from 30 to 48 inches apart. Special wire with shorter spacing can be secured. At intervals of 5 or 6 rods, special spreading links are provided so that the wire can be disconnected and passed

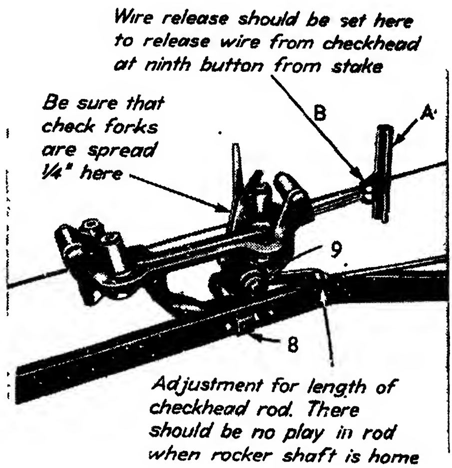


Fig. 12-7. Checking head of a check-row planter, showing check fork and automatic wire release at *A*.

around obstructions such as trees. When the planter is not being used, the wire is rolled up on a reel. The reels on most check-row planters are now provided with a wire guide to keep the wire level on the reel as it is reeled up. There is considerable loss of time in handling the check wire and anchor stakes when a check-row planter is used. Hansen[4] found that approximately half the time required to plant a field with rows 20 rods long was consumed in handling the check wire and the stakes. When the rows were 160 rods long, the time required ranged from 10 to 20 per cent, depending upon the speed of operation and the type of stake used. The graph in Fig. 12-8 shows the effect of stake-setting time and operating speed.

Valves for Check-row Planters. Most check-row planters have two valves in the boot or shank (Fig. 12-3). One of these is located at the top of the boot just under the seed plate, while the other is at the bottom of

[4] H. V. Hansen, Time and Labor Saving Possibilities of a High-speed Drill Planter, *Agr. Engin.*, 24(10):387, 1944.

the boot and in the rear part of the furrow opener. The two valves open and close at the same time. Kernels of corn accumulated on the top valve, while closed, are dropped and caught by the lower valve when the buttons on the wire trip the check fork and open both valves. Springs close the valves so quickly that the kernels do not have time to pass from the top valve into the soil before the lower valve closes.

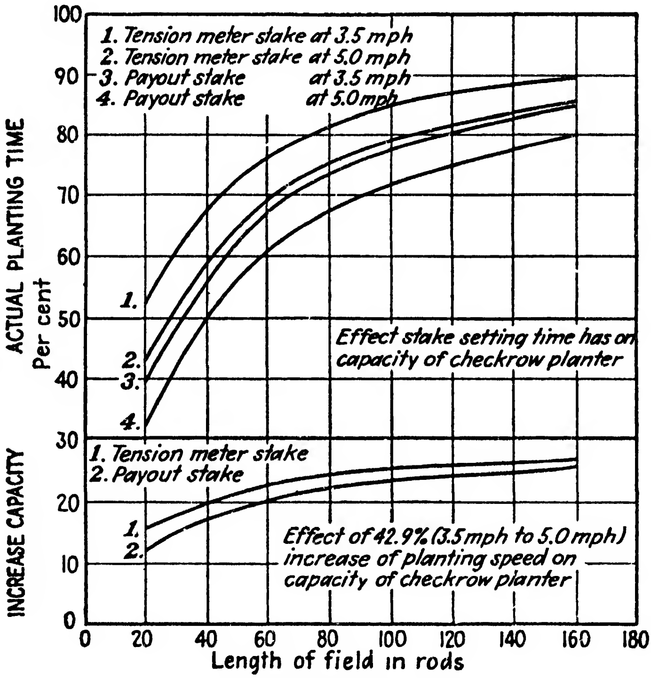


Fig. 12-8. The top part of the graph shows the percentage of time a check-row planter is placing seed in the soil with tension-meter and pay-out stakes when operated at 3½ and 5 m.p.h. The bottom part of the graph shows the increase in planting capacity because of 42.9 per cent increase in speed from 3½ to 5 m.p.h. [*H. V. Hansen, Agr. Engin.*, 25(10):387, 1944.]

The lower valve is necessary to prevent the hills being staggered and the kernels scattered. When drilling is desired, the valves can be locked open, allowing the seed to drop from the seed plate directly into the soil.

When planting at speeds of 5 m.p.h., it was found by Sandmark[5] that the valves designed for low speeds reacted differently at higher speeds. Three things affecting the dropping of the kernels in well-bunched hills

[5] A. C. Sandmark, Check-row Planting at Higher Speeds, *Agr. Engin.*, 25(10):386, 1944.

were found to be (1) the kernels bounced on the flat valves, (2) they did not fall in a compact bunch, and (3) there was a tendency to kick the kernels out and scatter them.

A high-speed wedge-shaped valve corrected these faults. With a V-shaped valve at the top of the boot and a smooth tube, the kernels stayed bunched as they dropped from the top to the bottom valve. With a V-shaped pocketlike valve which curved forward at the bottom of the boot, the kernels in the lower valve were in contact with the ejector and were pushed out in a compact bunch. Check-row planter valves have not been designed to operate accurately at speeds greater than 5 m.p.h. When planting at the higher speeds, the wire buttons, of course, pass through the checkhead faster.

Central-mounted Corn Planters. The central- or front-mounted planter shown in Fig. 12-9 consists of assembly units which can be quickly attached to or removed from the tractor. Six- and eight-row sizes are available.

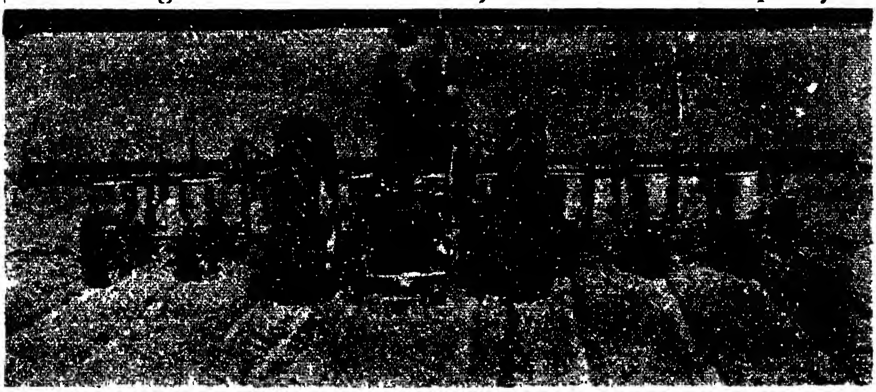


Fig. 12-9. Eight-row front-mounted corn and cotton planter. Gage wheels control the depth of planting for each flexible unit. Note the zero-pressure rubber press wheels. (*International Harvester Company.*)

Rear-mounted Corn Planters. This type of two-row corn planter has the same planting mechanism as the trailing-type corn planter. It is, however, directly connected to the tractor and raised and lowered by the tractor hydraulic lift (Fig. 12-10). In some cases, the planting mechanism is driven from the power take-off, while in other cases, the mechanism is driven from a sprocket on the tractor axle or by chains from the press wheel.

Lister Corn Planters. Figure 12-10 shows a four-row direct-connected quick-attachable power-lift lister corn planter equipped with middlebreaker bottoms for planting in hard ground. The planter is regularly equipped with 14-inch lister bottoms, disk coverers, and pre-emergence

spray equipment. Shovel coverers can be used in place of the disk coverers. Loose-ground lister planters are equipped with runner double-disk furrow openers.

Component Parts and Accessories for Corn Planters. The accuracy of a planter depends upon the uniformity of kernels, shape of hopper bottom, speed of the plate, shape and size of the cells, and fullness of the

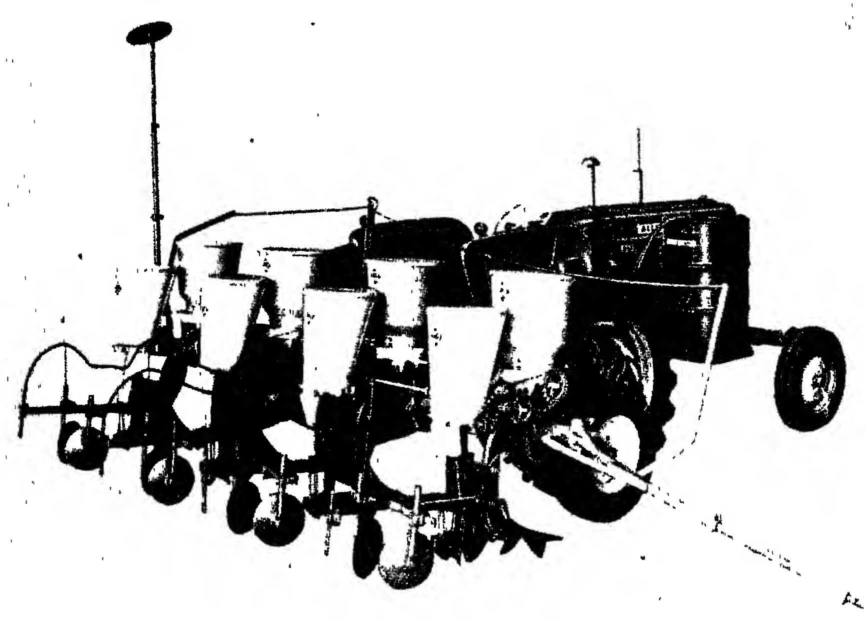


Fig. 12-10. Four-row rear-mounted lister-bedder planter equipped with hoppers for dry fertilizer and pre-emergence liquid spray tank and nozzle. (*Allis-Chalmers Mfg. Co.*)

hopper. A cone-shaped hopper bottom causes the seed to gravitate into the cells.

The yielding *cutoff* pawl (Fig. 12-11) acting under spring pressure pushes the extra kernels back as the cell passes under the plate cover, or it cuts them off from the cell and, at the same time, presses the kernel firmly into the cell. As the plate revolves to the point where the cell is over the seed tube, a yielding *knockout* pawl under spring pressure comes in contact with the kernel, knocking it through the cell into the

seed tube, where it is allowed to fall either upon the valve if checking or directly into the soil if drilling.

Four types of seed plates are used for planting corn, namely, the *edge-drop* and the *flat-drop*, which have the cells around the outer edge of the seed plate; the *flat-drop round-hole* type; and the *full-hill* plate. The

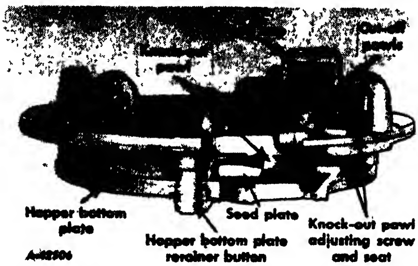


Fig. 12-11. Corn hopper bottom showing essential parts. (*International Harvester Company.*)

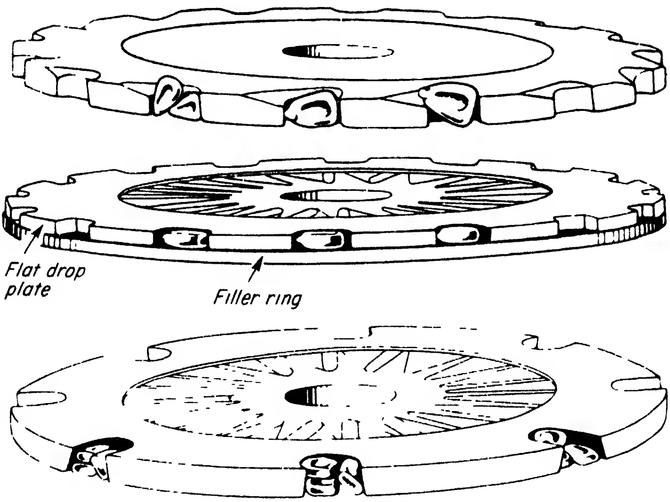


Fig. 12-12. Three types of seed plates for corn: *top,* edge-drop; *middle,* flat-drop; *bottom,* full-hill-drop.

edge-drop (Fig. 12-12) carries the kernel of corn on edge in the cell of the plate. The *flat-drop* (Fig. 12-12) carries the kernel flat in the cell of the plate.

The *full-hill plate* has cells around the outer edge large enough to admit several kernels at the same time. Sufficient kernels for one complete hill are dropped upon the valve without having to be accumulated (Fig. 12-12).

Kernels of corn do not vary greatly in thickness. They do, however, vary considerably in width and length. It is essential to select a plate having cells of sufficient thickness to prevent cracking the kernels as they pass under the cutoff cover plate. When the kernels are to lie flat in the cell, several plates are furnished, with cells adapted to small, medium, and large kernels. Both the edge-drop and the flat-drop plates do satisfactory work, provided the size of the cell suits the size of the kernel. In each type, the corn should be graded to a uniform size. This is more important in the edge-drop than in the flat-drop.

Furrow openers are necessary to open furrow-like trenches in the soil for receiving the seed as they are dropped by the mechanism of the planter. On check-row planters, four types are used: the *curved runner*, the *stub runner*, the *single-disk*, and the *double-disk*. The curved-runner type of opener is in most general use. The stub runner is suited to rough and stony ground. The double-disk opener is used where a wide furrow is desired.

Various types of attachments are shown in Fig. 12-13. A furrowing and covering attachment is shown in Fig. 12-13. The first blades push away the rocks and clods, permitting the rear covering blades to scrape in a sufficient quantity of earth to cover the seed.

Row markers are essential to keep the rows straight, parallel, and of equal distance apart (Fig. 12-2).

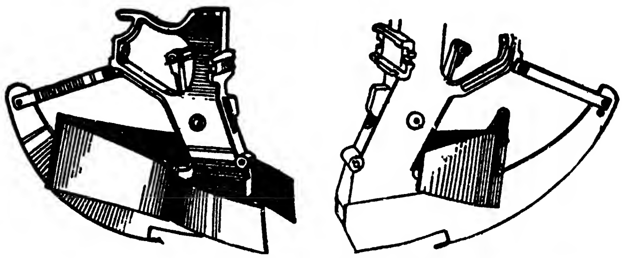
A fertilizer-distributing attachment can be mounted on any modern corn planter. The details of the types of feed and rate of distribution are discussed under Fertilizing Equipment. Some of the attachments on check-row planters, however, are provided with a valve that is operated by the check fork in unison with the valves of the planting mechanism. Some farmers use the regular planting mechanism to distribute fertilizer, but this cannot be done if the fertilizer is very sticky. When used in this manner, the planter should always be thoroughly washed afterward so as to prevent injury to the metal parts.

Plow-Plant. Attaching a soil packer and planter to the plow so that plowing and planting are done simultaneously is a growing practice by many farmers. This is what may be termed a minimum-tillage practice. Equipment is used to do as many jobs as possible in one operation. Experiments have been conducted in Indiana[6] with equipment designed to plow, plant, fertilize, and apply pre-emergent chemicals for weed control in one operation.

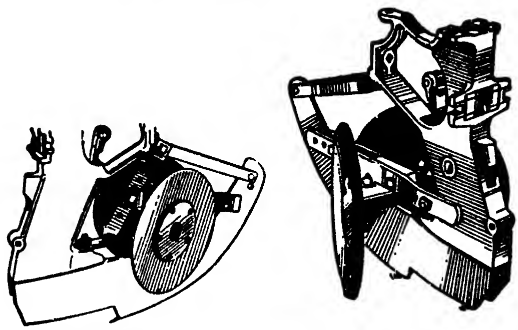
Tests on eleven corn farms gave yields of 10.9 bushels more corn where the combined equipment was used in comparison with separate plowing, planting, fertilizing, and pre-emergent application.

[6] C. M. Hansen, L. S. Robertson and B. H. Grisby: Plow-Plant Equipment Designed for Corn Production. *Amer. Soc. Agr. Engin. Trans.*, 2:65–67, 1959.

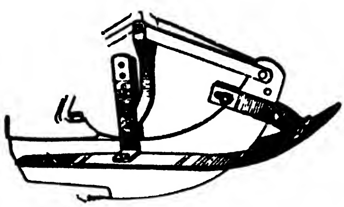
In some areas cotton farmers combine two or more operations into one. Where a rear-mounted planter is used on bedded land, a forward-mounted cultivator is used to cultivate the beds and kill weeds ahead of the planter. Fertilizer attachments, press wheels, and pre-emergent sprays



Blade-furrowing attachments



Nine-inch disks Eleven- to thirteen-inch disks
Disk-furrowing attachments



Gage-shoe attachment

Fig. 12-13. Attachments for runner furrow openers on corn planters. (*International Harvester Company.*)

are used with the planter. Figure 12-14 shows planter equipment that performs several operations at the same time.

Planting in the wheel tracks of the tractor is done largely to obtain a firm soil in which to place the seed to obtain moisture for germination. This is especially true where the farmer wants to plant in loose soil.

The combined use of equipment to do several jobs in one operation is limited only by the ingenuity of the farmer.

Cotton Planters. Cotton planters are often termed *cotton and corn planters* as the seed-dropping or seed-metering mechanisms for cotton and corn are interchangeable for the same hoppers. Undelinted cottonseed is covered with a coating of short fiber. This lint fiber causes the seeds to cling together in the hopper, and they do not flow into the seed plate cells as do the hard, smooth seeds of corn. Therefore, the dropping mechanisms in the hopper must differ in design in order to handle the two types of seed. Most cottonseed now used for planting are mechanically or chemically delinted.

Cotton is grown under climatic conditions that range from dry land conditions requiring irrigation to humid conditions receiving 70 to 80 inches annual rainfall. The soil types range from light, sandy loams to heavy clay. There are many types of farming practices and methods of preparing the seedbed for the planting of cotton. These practices and methods vary greatly with the climatic conditions and the soil types. Consequently, cotton is usually planted on beds in the more humid regions and in the furrow in the subhumid areas. Farmers who have well-drained soils in the humid areas may plant on flat-prepared land. Some irrigated land is prepared flat for the planting of cotton.

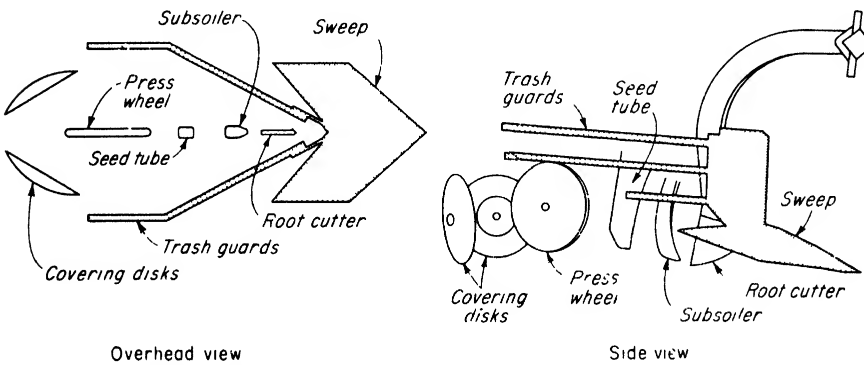


Fig. 12-14. Overhead and side views of a til-plant-type of lister planter developed in Nebraska.

These different planting practices require different types of planting equipment for planting on the bed, in the furrow, and on level, flat-prepared land. In an effort to furnish planters to meet these varied requirements, most manufacturers supply several models of planters. The principal differences in the models are the manner of mounting the planter on the tractor, the equipment for making the seed furrow, and the method of covering the seed as required for the different farming practices.

Central-mounted Cotton Planters. When the planter is mounted between the front and rear tractor wheels, it is central-mounted, although some manufacturers term this location as *front-* or *forward-mounted.* The planter is in front of the operator but not in front of the tractor. Cotton planters can be mounted centrally on any size row-crop tractor. They are available in one-, two-, and four-row sizes to suit the one-plow-, the two-plow-, and the four-plow-sized tractors.

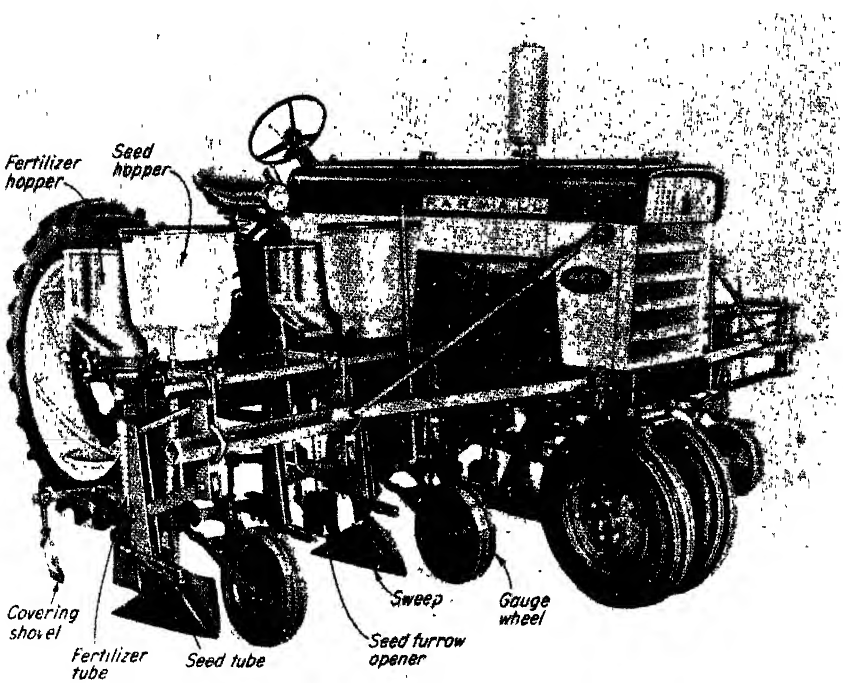


Fig. 12-15. Central- or front-mounted four-row blackland planter equipped to plant bedded land. (*Deere & Co.*)

The planter shown in Fig. 12-15 is especially designed for planting bedded lands. It is equipped with a large sweep to cut off and throw aside the dry topsoil of the bed. A small shovel mounted behind the sweep opens a furrow for the seed. Two covering shovels throw soil over the seed.

Most central-mounted cotton and corn planters can be adapted for planting in the bed, in the furrow, or in level flat land. They are lifted and lowered by hydraulic power lifts.

Rear-mounted Cotton Planters. This type of planter is available in two-, four-, and six-row sizes. Figure 12-16 shows a six-row rear mounted cot-

ton planter equipped to plant bedded land. Middlebreaker bottoms can be substituted for the sweeps to plant in the furrow. Rear-mounted planters are available with runner-knife seed furrow openers for planting land prepared flat. Hydraulic power lifts are used to raise and lower the equipment. Fertilizer attachments can be used with this type of planter.

When the rear-mounted cotton planter is equipped with middlebreaker bottoms, hoppers, furrow openers, and covering devices so that the seed can be planted in the furrow behind the bottom, it is termed a *lister planter* (Fig. 12-17). When cotton is planted in the furrow, the land is usually relisted in the planting operation.

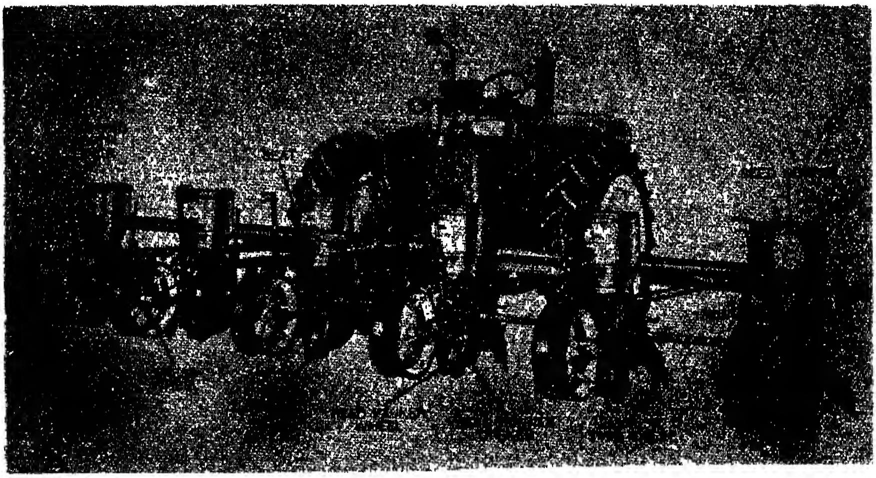


Fig. 12-16. Six-row rear-mounted planter equipped to plant on either flat or bedded land. (*Deere & Co.*)

Cotton-dropping Mechanisms. Gin-run cottonseed is extensively used for planting. This is seed with lint adhering to it, just as it comes from the cotton gin. Delinted cottonseed is becoming popular in many sections. Two types of dropping mechanisms are used on cotton planters. They are the *cell drop* and the *picker-wheel drop*.

The Cell Drop. A typical cell drop is shown in Fig. 12-18. It consists of a plate with cells on the outer edge. As the plate turns, the agitators separate and stir the seed, causing them to work down into the cells off a sloping collar and under feed springs which gently force more or less seed into each cell. Then the yielding cutoff pushes back the surplus, and as the cells pass over an opening, a yielding spring-controlled knockout partially drops into the cell, forcing the seed through the plate into the spout below. A small wheel with spurlike fingers projecting into each cell is also used as a knockout device.

With average-sized seed, the quantity dropped by the cell drop ranges

from 16 to 36 pounds per acre. A pound of average-sized cottonseed will contain approximately 4,500 seed. Therefore, if the planting rate is 30 pounds of seed per acre, about 135,000 seed are planted. Some authorities claim that under favorable conditions 70 per cent of the seed planted will

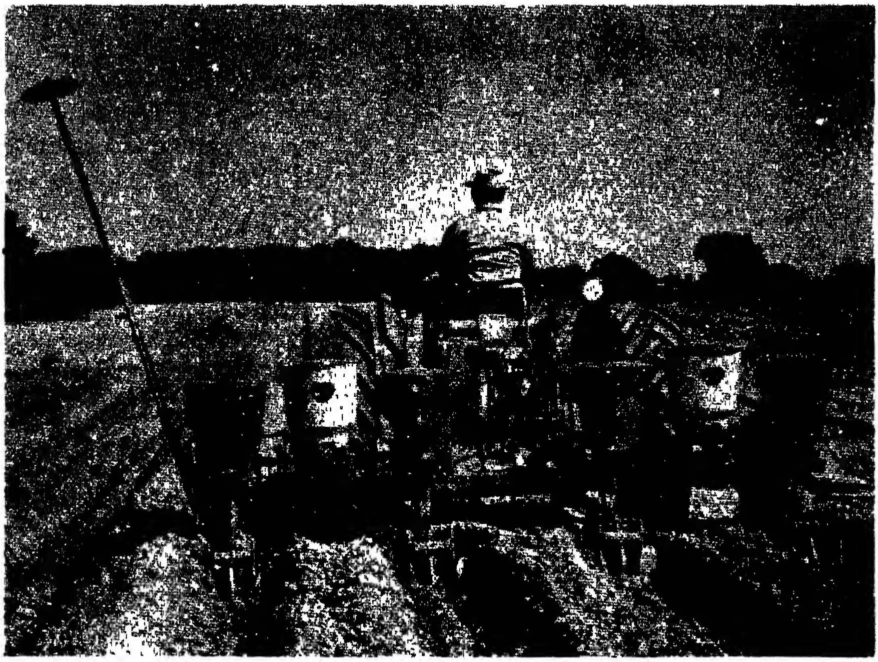


Fig. 12-17. Four-row lister planter equipped with fertilizer attachment. (*Deere & Co.*)

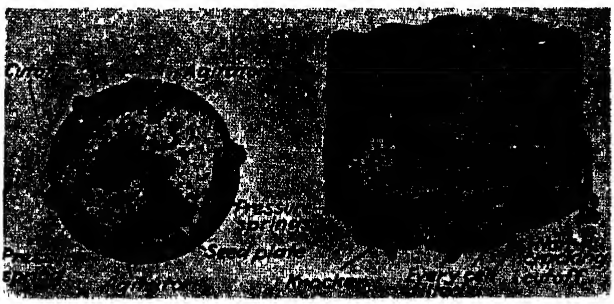


Fig. 12-18. Cell-drop cotton-dropping mechanism showing the various parts.

produce seedlings. If cotton is planted early, the expected percentage of seedlings may be reduced to around 50 per cent. The quantity of seed planted per acre is varied by changing the speed of the plate and by using plates which have different-sized cells.

The Picker-wheel Drop. This type of drop is also called a *reverse-feed* drop because the agitator spider plate in the bottom of the hopper revolves in one direction while the small picker which is located under the outer edge of the hopper bottom revolves in the opposite direction (Fig. 12-19).

The quantity of seed is regulated by exposing more or less of the picker wheel to the seed by means of a sliding gate shutter. The quantity of average-sized cottonseed planted can be varied from about 14 to 90 pounds per acre. The average planting rate ranges around 22 pounds per acre. The standard weight of a bushel of cottonseed is 32 pounds.

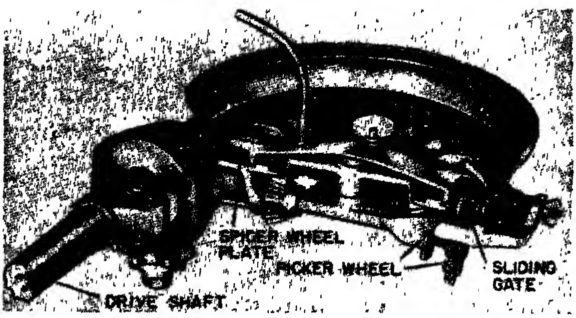


Fig. 12-19. Cross section of hopper bottom showing cotton plate and picker wheel in position. (*Deere & Co.*)

Hill-drop Mechanisms. The first hill-drop mechanisms used consisted of cells spaced at suitable intervals in the planter plate and large enough to hold sufficient seed for one hill or of picker wheels having the notches in their surfaces so spaced as to drop the seed in hills. These hill drops were located in the bottom of the planter hopper, and it was necessary for the seed for each hill to fall from the hopper through the seed tube to the soil. In falling a distance of some 18 or 20 inches, the seed became separated and scattered along the furrow to such an extent that it was difficult to distinguish one hill from another. Straight plastic seed tubes have less friction than steel, and there is less scattering of the seed. Later, someone conceived the idea of placing a valve in the lower part of the seed boot, low enough to the ground to prevent the seed from scattering when they were dropped.

Oates[7] found that cottonseed fell from the seed plate in a trajectory curve instead of straight down into the seed tube. The curvature of the trajectory changed when the speed of the plate was varied. A tapered seed tube 3½ inches at the top permitted bunches of seed to fall a dis-

[7] W. J. Oates, *Okla. Agr. Expt. Sta.*, unpublished data.

tance of 30 inches without excessive scattering on a greased board. Bunches of free-falling cottonseed from the hopper of a planter moving 4 to 5 m.p.h. along the row are likely to scatter in the furrow because of kinetic energy.

Most cottonseed are hill-dropped by means of a three-celled rotor attached to the furrow opener. A rotor 6 inches in diameter permits hill-drop planting at high speeds.

Planting to a Stand. The term *planting to a stand* means that the rate of planting, or pounds of seed planted per acre, is selected to give the desired stand of plants with no thinning.

Research workers have collected considerable data as to the optimum plant population of various crops that will give the highest yield, low-cost weed control, and high machine harvesting efficiency under different climatic and soil-fertility conditions. Under average conditions the plant population for cotton per acre should be between 40,000 and 50,000. For corn 15,000 plants per acre are considered to give optimum yields.

Planting seed should be tested for the germination percentage. It cannot be expected that field conditions will give as high germination as was obtained in the germinator. Therefore, an allowance should be made in the number of seed placed in the soil and the number increased to take care of the field mortality and poor field germinating conditions.

Component Parts and Attachments for Cotton Planters. The germination of cottonseed is greatly influenced by the type of *furrow opener* used. No loose soil should be permitted to fall into the furrow before the seed come to rest in the furrow. The soil in the bottom of the furrow should be firm and moist. Tests conducted by the author[8] indicated that a narrow runner-type opener disturbed the soil to a lesser degree than shovel openers. Less loose soil is likely to fall into the furrow under the seed. Generally, better stands were obtained with the runner opener, especially when a boatlike piece of metal was attached to the bottom of the runner in the notch just ahead of the point where the seed drop between the side extensions of the runner (Fig. 12-20). This boatlike piece firms the soil in the bottom of the furrow. This type of furrow opener is called a modified runner opener.[9]

Wings attached to each side of a runner furrow opener (Fig. 12-21) aid in pushing extra soil, roots, and clods into the middle. This action permits and aids in the preparation of a drill for the application of pre- and post-emergence herbicides.

[8] H. P. Smith and M. H. Byrom, Effects of Planter Attachments and Seed Treatment on Stands of Cotton, *Tex. Agr. Expt. Sta. Bul.* 621, 1942.

[9] Rex. F. Colwick et al., Planting in the Mechanization of Cotton, *Southern Cooperative Series Bul.* 49, 1957.

Figure 12-22 shows a narrow shovel-type furrow opener with rigidly attached *soil shields* and a narrow soft-rubber-tired wheel to roll lightly on the seed before they are covered. This is called a *seed press wheel,* as it rolls on the seed before they are covered. The narrow furrow opener is used on lister planters to place the seed in the furrow where the soil

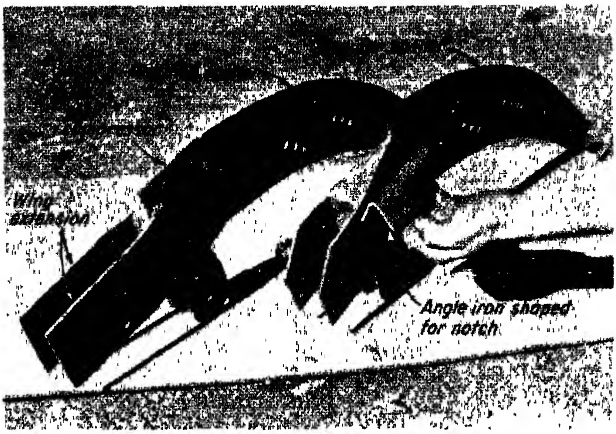


Fig. 12-20. Method of modifying a runner opener to firm the soil in the bottom of the furrow. (*Texas Agricultural Experiment Station.*)

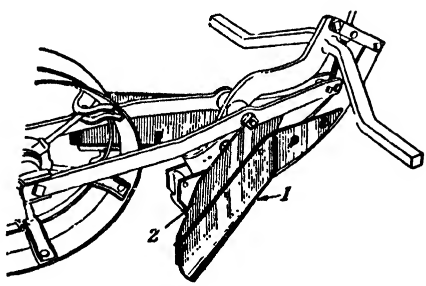


Fig. 12-21. Wings, used on each side of a furrow opener, push sticks, clods, and extra soil to the middle and leave a level bed. A level bed is essential for the application of pre- and post-emergence chemicals for weed control and for flame cultivation.

is moist. The ridges give some protection to the young seedlings from blowing sand.

Several kinds of *covering devices* are used on cotton planters. These include *open-center press wheels, shovels, disks,* and *scrapers.* The soil thrown over the seed by the covering devices should be pressed firm to hold the moisture in the soil around the seed. Where the soil is sandy, steel open-center press wheels can be used as an attachment on the planter. A moist clay soil will usually stick to a steel wheel, and there-

fore, in this case, the press wheel is removed and the soil rolled in a separate operation with a two- or four-wheel roller (Fig. 12-23). This is

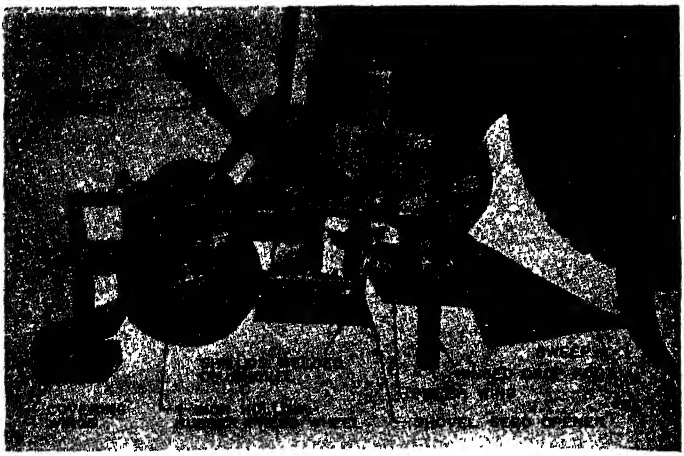


Fig. 12-22. A small hollow-rubber-tired wheel attached behind the furrow opener, to run on the seed before covering, compresses the soil around the seed to hold the moisture around it and thus aid germination in some areas. (*Texas Agricultural Experiment Station.*)

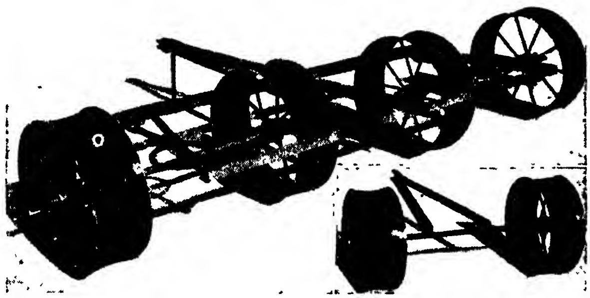


Fig. 12-23. Two- and four-row seedbed rollers are used where the soil sticks to the steel press wheel of the regular planter. This type of roller is used after the soil dries, and the method is termed *delayed rolling*. (*E. L. Caldwell & Sons.*)

termed *delayed rolling*. Figure 12-16 shows a planter equipped with a zero-pressure hollow-rubber tire on the press wheel. Where the soil is in good tilth for planting and not too moist, it does not stick excessively to the flexing rubber.[10]

The Application of Fungicides. Healthy stands of cotton seedlings are often severely damaged or almost destroyed by soil-borne organisms, such as soil fungi that attack the tender living root tissue. Such fungi can be con-

[10] H. P. Smith and E. C. Brown, Mounting for Pre-emerge Press Wheel-rollers and Sprayer Nozzles, *Tex. Agr. Expt. Sta. Prog. Rpt.* 1520, 1952.

trolled by spraying 5 pounds of fungicide mixed and applied with 7.8 gallons of water per acre at a ground speed of about 4 m.p.h.[11] The fungicide is applied as a part of the planting operation (Fig. 12-24). The spray should cover a band 1½ to 2 inches wide from the bottom of the seed furrow to and including the surface of the covering soil.[12]

Fertilizer Attachments. These are available for most cotton and corn planters (Figs. 12-10 and 12-15). When granular fertilizer is applied as

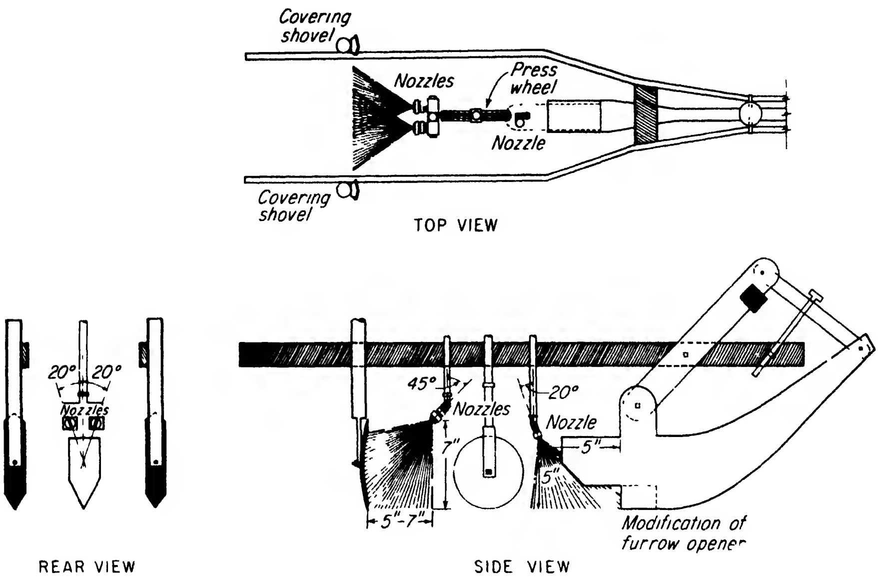


Fig. 12-24. Arrangement of furrow opener, spray nozzle, and covering shovels for applying fungicide in the furrow on the seed for mixing with the covering soil. (*Texas Agricultural Experiment Station.*)

a part of the planting operation, the fertilizer should be placed in a band either on one side or on both sides of the seed row from 2 to 2½ inches to the side of and from 2½ to 3 inches below the seed level.[13]

[11] L. S. Bird and C. D. Ramsey, Fungicides Mix with the Covering Soil at Planting Time for Seedling Disease Control, *Tex Agr. Expt Sta. Prog. Rpt.* 2003, 1958.

[12] William H. Aldred, Application of Soil for Controlling Cotton Seedling Diseases, Paper presented to the Southwestern Section, American Society of Agricultural Engineers, April, 1962.

[13] H. P. Smith, M. H. Byrom, and H. F. Morris, Germination of Cottonseed as Affected by Soil Disturbance and Machine Placement of Fertilizer, *Tex. Agr. Expt. Sta. Bul.* 616, 1942.

H. P. Smith, H. F. Morris, and M. H. Byrom, Machine Placement of Fertilizer for Cotton, *Tex. Agr. Expt. Sta. Bul.* 548, 1937.

H. P. Smith and D. L. Jones, Mechanized Production of Cotton in Texas, *Tex. Agr. Expt. Sta. Bul.* 704, 1948.

Sorghum, Pea, and Peanut Planters. The corn and cotton planters can be used for the planting of sorghum, peas, and peanuts by removing the corn or cotton plates and putting in plates designed for the planting of the desired seed.

Hurlbut[14] found that more satisfactory seeding rates were obtained by using plates made especially for sorghum rather than by attempting to use a regular or revamped corn plate. He also found that the lower part of the plate seed hole should be taper-reamed to prevent sorghum seeds

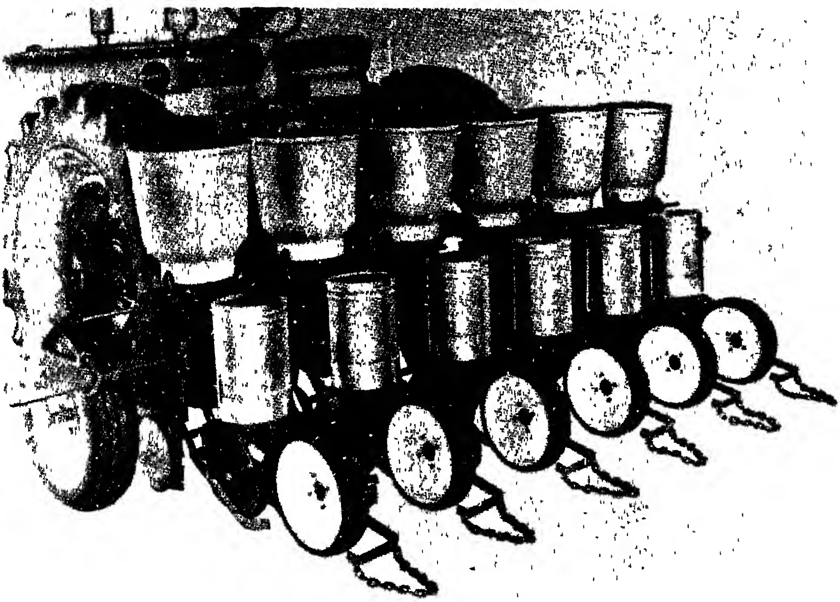


Fig. 12-25. Six-row rear-mounted beet and bean planter equipped with fertilizer distributors and rubber press wheels. (*International Harvester Company.*)

sticking in the hole and clogging it. A 15-degree bevel of the seed hole on the upper side helped to prevent the seed from wedging between the sharp edge of the hole and the cutoff.

The number of seed per pound varies with different varieties of sorghum as shown in Table 12-1.

Beet and Bean Planters. The production of beets for sugar and soybeans for oil and plastics has brought about new developments in planting equipment for these crops. Figure 12-25 shows a six-row beet and bean planter. Adjustments are provided to obtain a wide variety of row spac-

[14] L. W. Hurlbut, Adjusting Corn Planters and Listers for Sorghums, *Nebr. Agr. Expt. Sta. Cir.* 64, 1940.

ings—13 to 40 inches. The six-row machine can be adjusted to row spacings varying from 18 to 24 inches. When the machine is converted into a four-row planter, row spacings can be obtained ranging from 26 to 40 inches. The planter can be used for planting other field crops in narrow rows.

TABLE 12-1. NUMBER OF SEED PER POUND FOR SIX VARIETIES OF SORGHUM

Variety	*Number of seed per pound*
Sooner Milo	12,600
Feterita	15,900
Atlas Sorgo	20,900
Pink Kafir	22,400
Early Kalo	23,200
Early Sumac	33,400

Seed plates are obtainable for planting beans, soybeans, corn, beets, and other small-seed crops. The dropping mechanism for beets is designed to plant *segmented seed,* that is, plant single beet seed after the pods have been broken up. Some planters are designed to plant pelleted seed. Special brush cutoffs (Fig. 12-26) and small spurlike rollers with projections to punch the seed through and out of the plate cell (Fig. 12-27) are available. Various-sized sprockets are provided to obtain up to twelve different plate speeds. Runner and double-disk types of furrow openers are interchangeable. The double-disk opener is provided with removable depth-gage bands or drums that fit on the sides of the disks. Narrow and pointed-shoe-type furrow openers for fertilizer are attached to the planter gangs so that the fertilizer can be placed to the side and below the seed level.

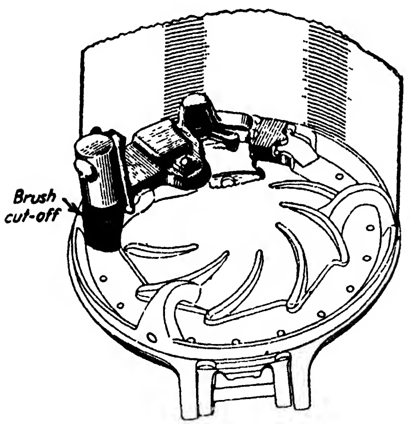


Fig. 12-26. Brush cutoff that can be substituted for the regular cutoff in seed hopper for planting beets.

Potato Planters. The slow laborious hand-dropping method of planting potatoes has been largely supplanted by mechanical planters that open a furrow, drop and space the seed pieces at various distances, place fertilizer to the sides and below the level of the seed, and cover both seed and fertilizer to the desired depth (Fig. 12-28). There are three types of potato-dropping mechanisms: the *automatic*, the *high-speed automatic*, and the *semiautomatic.*

Automatic. The dropping mechanism of the automatic potato planter consists of a picker wheel to which are attached from three to twelve picker arms (Fig. 12-29). The picker wheel revolving on the main axle causes the picker arms and picker head to pass through the picking chamber containing the seed. Each picker head is equipped with two

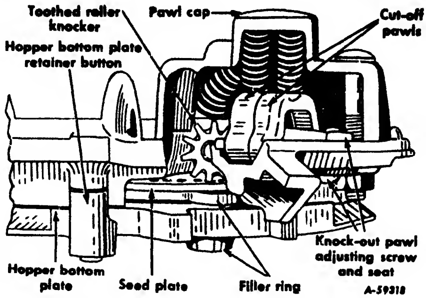


Fig. 12-27. Showing hopper bottom with parts for planting segmented beet seed. (*International Harvester Company.*)

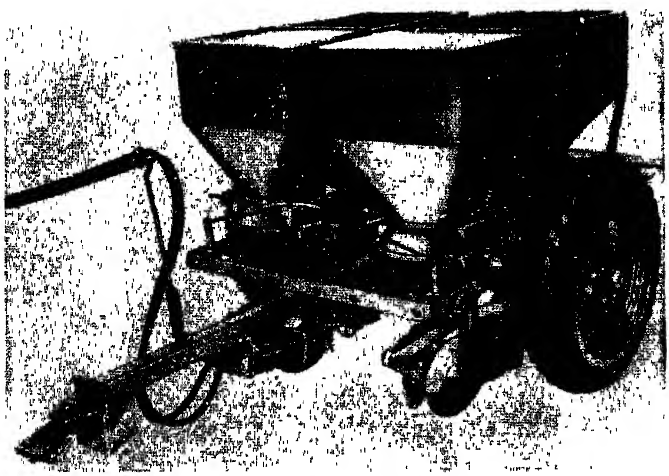


Fig. 12-28. Two-row trailing tractor-drawn potato planter equipped with fertilizer attachment and hydraulic remote-control cylinder to raise and lower the furrow openers. (*International Harvester Company.*)

sharp picking points which pick out a single seed piece, carry it over to the front, and, as the arm starts downward in its rotation, release the seed or force it off the points, dropping it into the seed spout, which guides it into the furrow made by the furrow opener. The seed piece is forced off the picker points by the opening of the picker arm when the base of the arm contacts a cam. The distance between seed pieces in the furrow is varied by changing the speed of rotation of the picker wheel. The quan-

tity of seed flowing into the picking chamber is controlled automatically. A man rides on the two-row tractor-drawn planter to see that the hoppers are kept full and that the picking chamber does not choke.

High-speed Automatic. The high-speed automatic potato planter is equipped with two picker wheels, each having eight picker arms. These two picker wheels revolve only half as fast as a single picker wheel used

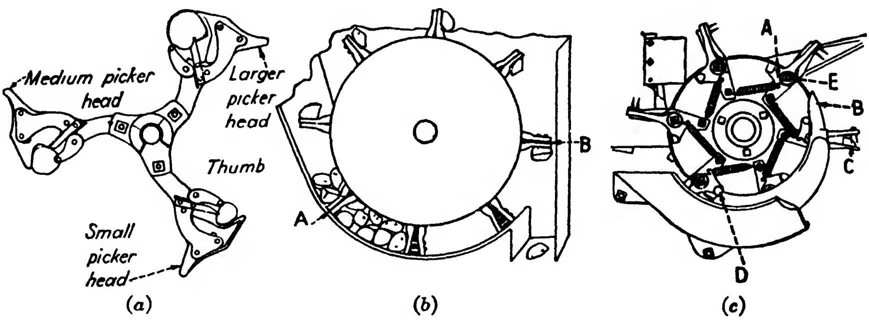


Fig 12-29. Three makes of picker wheels for automatic potato planters. Only one size of picker head is used at one time. *a*, Picker wheel showing three sizes of picker heads, *b*, picker wheel and arms, with housing cut away to show how seed pieces are picked from the picker chamber, *c*, picker wheel showing how cams open the picker arm jaws to release the seed piece.

Fig 12-30 Assist-feed mechanism of the semiautomatic potato planter.

at a normal speed. High-speed planting is done at twice the normal speed, but the picker arms do not revolve any faster than does the single wheel.

Semiautomatic. The dropping mechanism for this type of planter is entirely different from that of the automatic type. The seed drops from an elevator wheel through a feed spout into the pockets of a revolving horizontal feed ring (Fig. 12-30), which carries the seed around to the opening over the seed spout through which it falls into the furrow. Should the

elevator fail to place a seed piece in each pocket of the feed ring, it is the duty of the man on the planter to fill the pocket. For this reason, this type of dropping mechanism is sometimes called an *assist feed mechanism*. If two pieces are placed in one pocket, the man can remove one of them. Spacing of seed is done by changing the feed rings. Feeds may have ten, twelve, fifteen, or eighteen pockets.

Attachments for Potato Planters. The soil of some potato-growing areas is low in fertility, and fertilizer attachments are used in combination with the planter to save the cost of a separate operation to apply the fertilizer. The potato is easily injured if it comes in contact with fertilizer, and for this reason the fertilizer is placed in bands to each side of and below the level of the seed (Fig. 12-31). Double-disk fertilizer openers have a 12-inch disk on one side to place the fertilizer about seed level and a larger disk on the other side to place the fertilizer deeper or lower in the soil. This method of applying fertilizer is called *hi-lo* (high-low) *application*. Stub-runner furrow openers are generally used on potato planters, but single- or double-disk openers can be obtained. Disks are used to cover and ridge the soil over the seed (Fig. 12-31). Either the shoe or disk type of row marker can be obtained. A double spout is available for placing the seed in twin rows (Fig. 12-32).

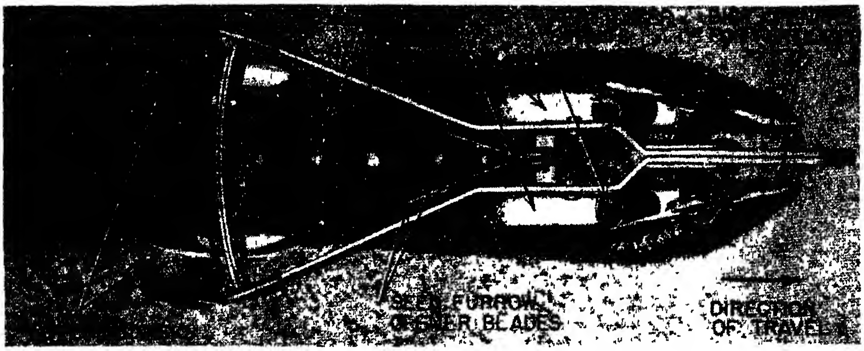


Fig. 12-31. Overhead view of potato-planter furrow-opener assembly showing disks for opening furrow for fertilizer, the opener blades for the seed piece, and the covering disks.

Tractor-drawn potato planters are made in one-, two-, and four-row sizes. The width between rows on the two-row planter can be adjusted for spacings ranging from 30 to 42 inches at 2-inch intervals.

Transplanting or Plant-setting Machines. When large quantities of plants such as cabbage, tobacco, tomatoes, and sweet potatoes are to be transplanted, time and labor can be saved by the use of a transplanting machine (Fig. 12-33). These machines have a device to open a small fur-

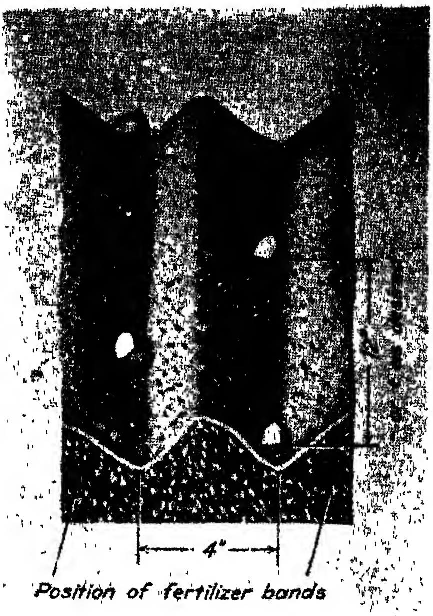


Fig. 12-32. Potatoes can be planted in twin rows.

Fig. 12-33. Two-row four-man tractor-mounted transplanter. Note the barrels of water mounted on each side of the tractor. (*Mechanical Transplanter Co.*)

row, a tank to supply water, and disks or blades for closing the soil over the fertilizer and about the plants. With a transplanting machine, it is not necessary to wait for seasonable weather, because the machine automatically pours a small quantity of water around the roots of each plant as it is being set. Under favorable conditions, with a one-row machine, 3 to 8 acres can be set to plants per day. Twice as much can be done with a two-row machine, or 6 to 16 acres per day.

Figure 12-34 shows a cross section of spring-steel fingers holding two rubber disks which are spread apart by rollers (shown at the top of Fig. 12-34) until a plant can be placed between the rubber disks. They are then allowed to close, to hold the plant until the disks revolve into the furrow, where the plant is released. Soil is pressed around the plant by angled press wheels.

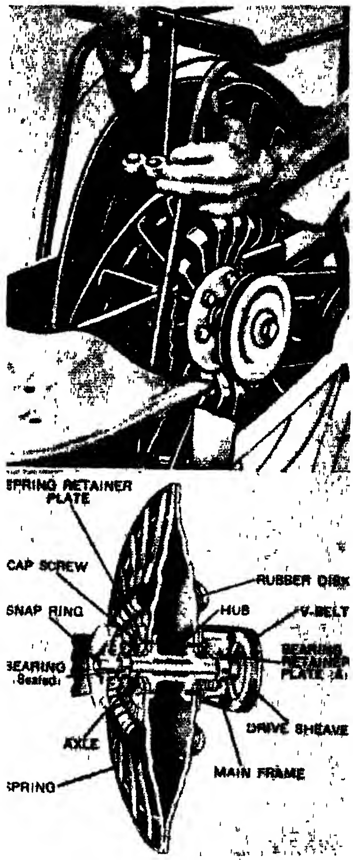


Fig. 12-34. Steel-spring fingers holding two rubber disks for transplanting plants. The top view shows rollers to spread the rubber disks so the plants can be placed between them. (*Deere & Co.*)

BROADCAST AND DRILL PLANTERS

Broadcasting is the oldest and simplest method of sowing seed. Broadcasting by machine is more accurate and rapid than by hand. Types of machine broadcasters are the *knapsack*, *endgate*, *two-wheel*, *weeder-mulcher*, and the *airplane*. Broadcast planters drop the seed on the surface of the soil and do not have any covering attachments. If covering is desired, the seeds are usually covered by harrowing. The *knapsack* seeder consists of a good-sized canvas sack fastened to a seeding mechanism, the whole being slung over the shoulders. A crank turned by hand revolves a wheel having several different radial ribs for scattering the seeds. The ribs throw the seeds out to the front and sides in a steady stream. The quantity of seed is regulated by a sliding gate. The wider the gate is opened, the more seed per acre will be sown. This type of seeder is good for sowing clover seed and small grass seed on lawns and fields in the early spring.

Figure 12-35 shows a tractor-mounted power-take-off-driven broadcast seeder. It consists of a hopper, a feeding device, and a distributing wheel.

There are two types of *two-wheel* horse-drawn broadcast seeders: the *narrow-track* and the *wide-track*. It is claimed that the narrow-track seeder is more practical when covering devices are not used. It also eliminates whipping of the tongue on rough ground. Both types use the fluted-wheel type of feed.

Fig. 12-35. Tractor-mounted power-take-off-driven broadcaster for seed, fertilizer, and dry chemicals. (*Herd Seeder Co.*)

The *weeder-mulcher* broadcast planter consists of a seedbox on a weeder-mulcher. The seed are dropped on the ground and then covered by the long spring-steel mulcher fingers.

Seeding attachments for land rollers can also be considered broadcast seeders.

The *airplane* can be considered as a type of broadcast planter and is used to plant rice, clovers, and other crops whose seed are sown broadcast. It is equipped with a special seeding tube that flares out at the rear and has curved sections which cause the seed to spread over a wide swath.

Grain Drills. The grain drill is a machine designed and built to place the seed of small grains and grasses in the ground in narrow-spaced rows at

a uniform depth. The principal parts are the main frame, transport and drive wheels, a box for the seed, a device to meter the seed out of the hopper in uniform quantities, furrow openers to open the furrows for the seed, and covering devices.

Tractor-operated grain drills can be divided into two types, namely, *trailing* and *mounted.* Most of the trailing types are supported by a wheel at each end of the drill (Fig. 12-36). This type is called an *end-wheel drill.* The wheels serve as ground traction drives to operate the moving

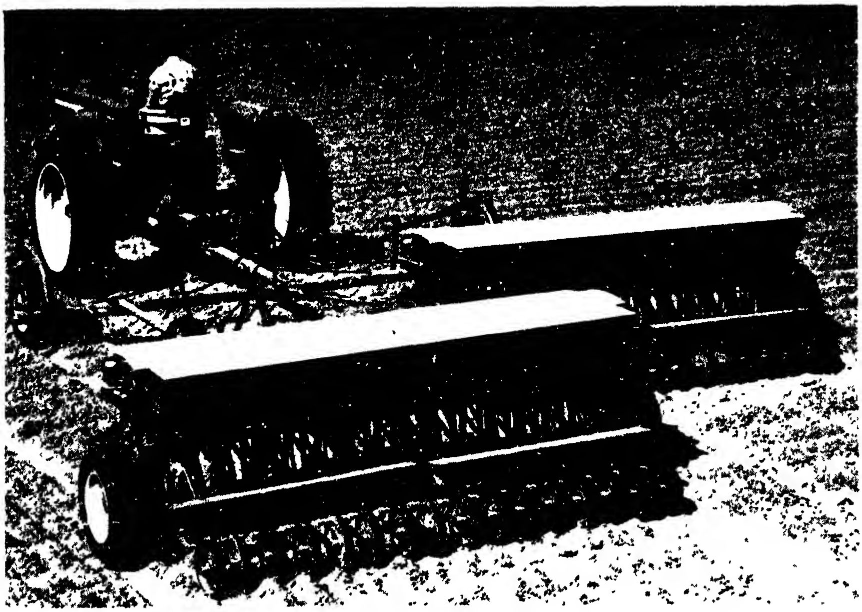


Fig. 12-36. Two grain drills attached to multiple hitch with remote-control hydraulic lifts. (*Deere & Co.*)

parts of the drill. Large drills are divided so that each end wheel drives half of the feeds. Hydraulic remote-control cylinders raise and lower the drill on the end wheels. *Trailing press-wheel* drills are partly supported by the large press wheels at the rear and partly by the hitch bar in front (Fig. 12-37).

Mounted grain drills are mounted on the tractor by the three-point hitch (Fig. 12-38). The drill feeds and other moving parts are driven by the power take-off of the tractor.

It is claimed that as much as 25 per cent more acreage can be sown with a mounted drill than with a trailing drill.[15] It can be operated at

[15] T. W. Edminister and H. F. Miller, Jr., *Advances in Agronomy,* vol. XI, p. 187, 1959.

faster field speeds, can be turned faster, and can be serviced more easily and quickly, as it can be backed up to the supply truck or trailer.

Grain drills are also classified as *plain drills* and *fertilizer drills*. A plain drill has a hopper and feeds for the drilling of seeds only, while the ferti-

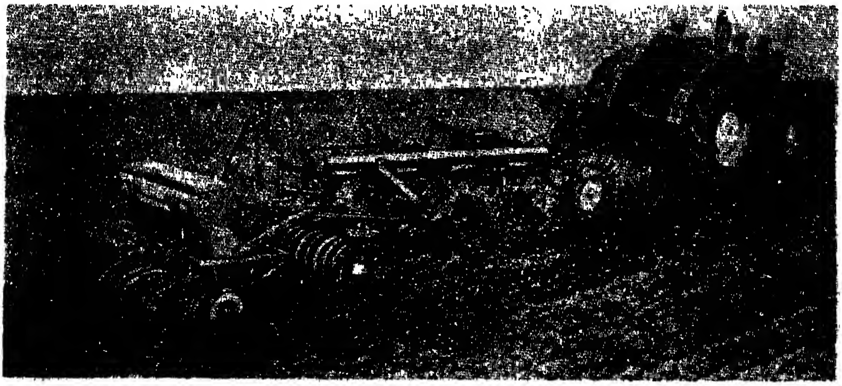


Fig. 12-37. Press-wheel-type grain drill being used behind plow and soil pulverizer. (*Oliver Corp.*)

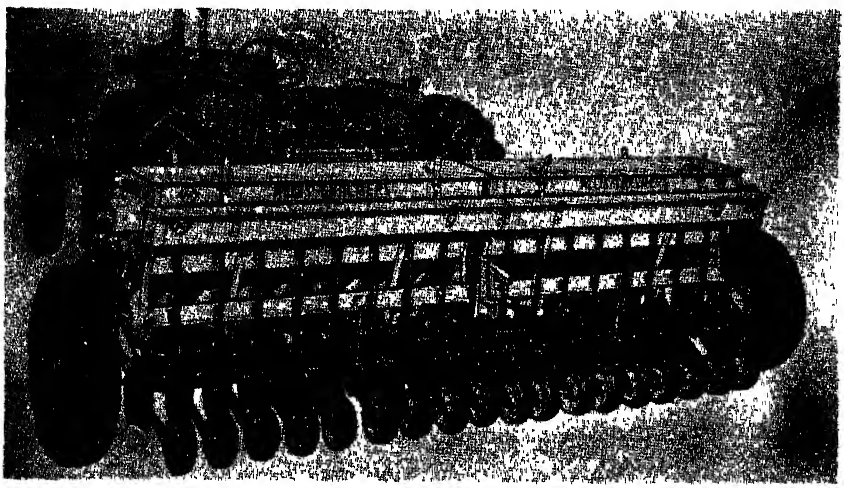


Fig. 12-38. Tractor-mounted combination grain, fertilizer, and grass drill. Rubber press wheels are used. (*Allis-Chalmers Mfg. Co.*)

lizer drill has a large seedbox which is divided lengthwise into two compartments, one for seed and one for fertilizer. Some drills are provided with grass-seed attachments (Fig. 12-39). The fluted force feed and the double-run feed are used on both the plain and fertilizer drills.

Size of Drill. The size of a grain drill is determined by the number of furrow openers and the distance they are spaced apart. The size is expressed as 12-6 or 18-7, which means there are 12 or 18 furrow openers spaced 6 or 7 inches apart. Drills can be secured with the feeds and furrow openers spaced 6, 7, or 8 inches apart. A 27-7 drill will seed a strip 19½ feet wide. The deep-furrow-type drill may have the furrow openers spaced 10, 12, and 14 inches apart. When grain drills are used to plant

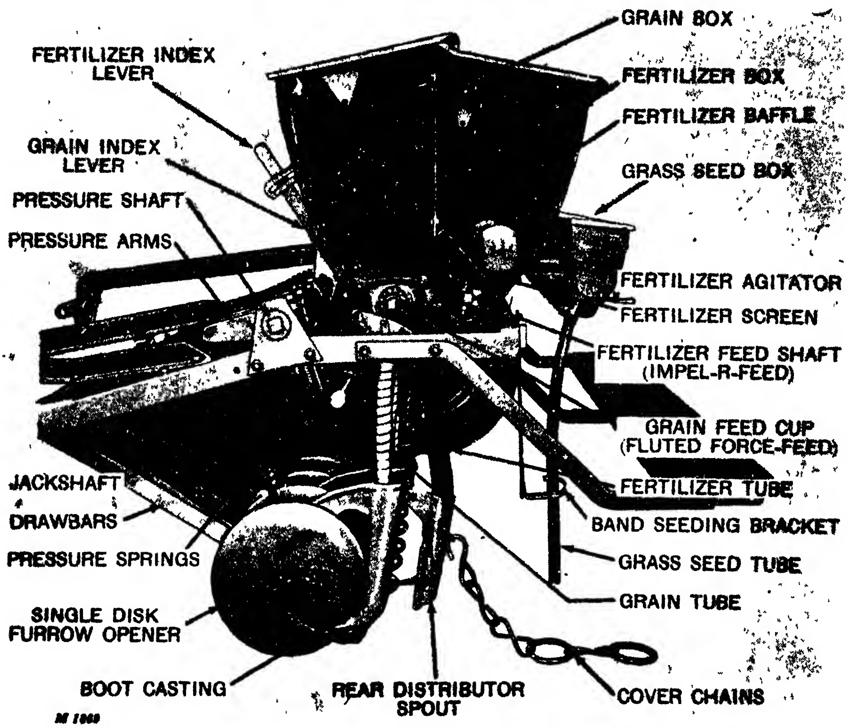


Fig. 12-39. Cross-sectional view of combination grain, fertilizer, and grass drill with parts named. Drag chain covers are used. (*Deere & Co.*)

crops in rows spaced far enough apart to permit cultivation, some of the feeds must be covered (Fig. 12-40). Table 12-2 shows the feeds used for different-sized drills and two-row spacings.

Frame. The frame is usually made of angle steel, well braced and reinforced at the corners. It is necessary that the frame be strong enough to prevent sagging and to hold the parts in alignment, as all parts are connected to the frame. The axle is carried beneath, with the wheels on each end of it. The seedbox is carried above, while the furrow openers are suspended below. Roller bearings are usually used on each end of the axle.

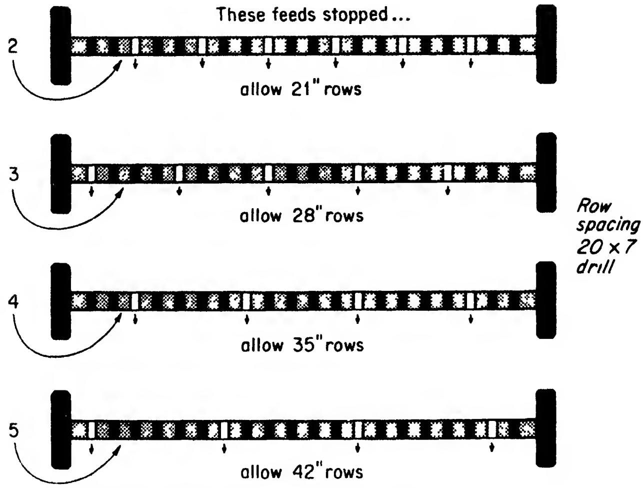


Fig. 12-40. Showing methods of stopping feed cups to plant crops in rows with grain drills.

Wheels. Most grain drills are equipped with rubber-tired wheels. These wheels are placed on the main axle of the drill. When smaller rubber-tired wheels are used on this equipment, they are placed on a stub jackshaft to elevate the drill to its regular height, so that the same

TABLE 12-2. FEEDS* TO USE FOR WIDE ROW SPACING

All other feeds must be covered with stops

7-inch-spaced drills

Drill	21″ row	28″ row	35″ row	42″ row
9 × 7	3–6–9	1–5–9	3–8	2–8
11 × 7	3–6–9	2–6–10	1–6–11	3–9
13 × 7	1–4–7–10–13	1–5–9–13	2–7–12	1–7–13
15 × 7	1–4–7–10–13	2–6–10–14	3–8–13	1–7–13
17 × 7	3–6–9–12–15	2–6–10–14	2–7–12–17	3–9–15

8-inch-spaced drills

Drill	24″ row	32″ row	40″ row	48″ row
16 × 8	1–4–7–10–13–16	3–7–11–15	1–6–11–16	2–8–14

* The feeds are numbered 1 to 17.

drawbars and pressure rods and springs can be used with either type wheel. The implement tire size for grain drills is usually 6.70 × 15. The operator's manual should be studied to determine if a correction factor should be used in setting the seeding rate.

Seedbox. The seedbox is made of sheet metal and should have a large capacity. A tight-fitting lid should be provided to keep out rain. Inside the box near the bottom are one or two power-driven agitator rods that extend the full length of the box to agitate and prevent the seed from *bridging over* as the seed are fed out. The grain feeds are set in the bottom of the box and are of two types: the fluted-wheel and the double-run feed.

Fluted-wheel Feed. The fluted-wheel feed is considered the simpler of the two and is the more generally used. It has a greater number of seeding-rate settings and is easier to clean than the double-run feed. It consists mainly of a fluted-wheel feed roll, feed cutoff, and an adjustable gate. Figure 12-41 shows that the feed roll and the cutoff are mounted on a square shaft running through the feed cups. The feed roll turns with the shaft, forcing the grain out over the gate, where it falls into the seed tube. The gate is adjustable for different-sized seeds. Power is transmitted from the main axle to the feed shaft by gears or sprockets and chains.

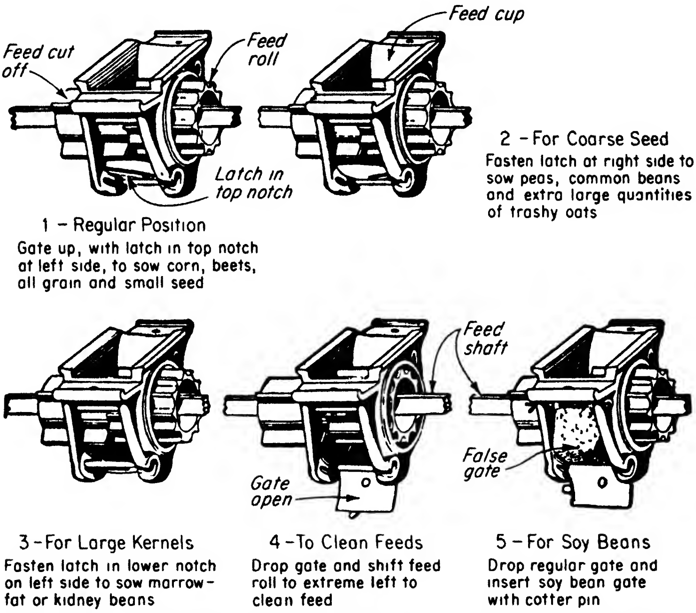


Fig. 12-41. Fluted-wheel grain feed showing various adjustments.

The quantity of seed sown per acre is varied by exposing more or less of the feed roll to the seed inside the feed cup and by adjusting the gate. Figure 12-42 shows a typical indicator plate used to adjust the fluted feed roll to sow the desired quantity per acre.

Internal Double-run Feed. This feed, shown in Fig. 12-43, gets its name from its construction. It consists of a double-faced wheel having a small and a large side. The small side is used for planting small seeds, while the large side is used for planting larger seeds such as oats, wheat, peas, and beans. Figure 12-43 shows one side covered while the other is in use. The lid is hinged over the middle of the wheel so it can be reversed to cover either side.

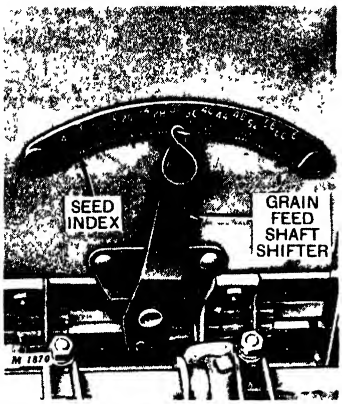


Fig. 12-42. Seeding-rate indicator for grain drills. (*Deere & Co.*)

The quantity of seed sown per acre is changed by varying the speed of the feed wheels. Figure 12-44 shows an arrangement for changing the speed. Special attachments to reduce the size of the outlets and adjustable gates also aid in regulating the quantity of seed sown per acre.

Land Measures. Grain drills are all equipped with a small device, similar to the one shown in Fig. 12-45, which is called a *land measure, acre meter,* or *surveyor.* This is an instrument so designed that it determines the number of acres sown. If the operator keeps a record of the number of bushels placed in the seedbox and the number of acres sown, a check can be made as to the accuracy of the drill in the amount of seed being sown per acre. This is *not* termed *calibration,* which is described below.

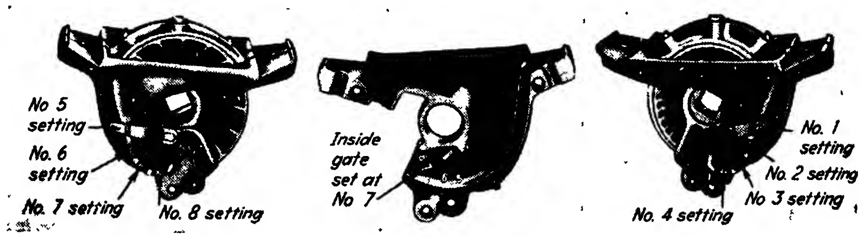


Fig. 12-43. Internal double-run type of grain-drill feed showing gate position for seeding rate.

Calibration of Grain Drills. Many grain drills do not sow accurately, even though the indicator on the dial plate is set correctly. Some will sow more seed than the dial indicates, while others will sow less. Oftentimes the operator will attempt to check the drill in the field by measuring off a certain acreage, seeding it, and then determining the amount of seed sown. At best, this is a very poor method of checking a drill.

The method of calibrating a drill is as follows: First, find the width of the strip the drill will sow. Measure the distance between furrow openers and multiply it by the number on the drill. Next, find the length of the strip of that width necessary to make 1 acre. This is done by dividing 43,560—the number of square feet in 1 acre—by the width of the strip sown by the drill. The result will be the distance the drill must travel to sow 1 acre of grain.

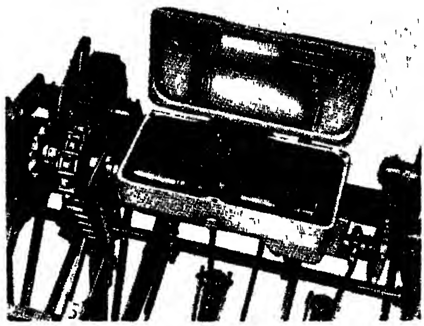


Fig. 12-44. Gear system for varying the speed of the feed wheel and quantity of seed sown by grain drills (*Oliver Corp.*)

Now find the number of times the wheels on the drill will turn in going this distance by dividing the distance to be traveled by the circumference of the wheel.

Fill the seedbox with grain.

Set the indicator on the scale to sow whatever quantity of seed is desired.

Jack up the drill and place a paper bag under each seed tube. Tie a rag around the tire of the measured wheel so each revolution can be counted.

Engage the clutch and turn the wheels, counting each revolution. Turn them at about the speed they would travel in the field. When the wheels

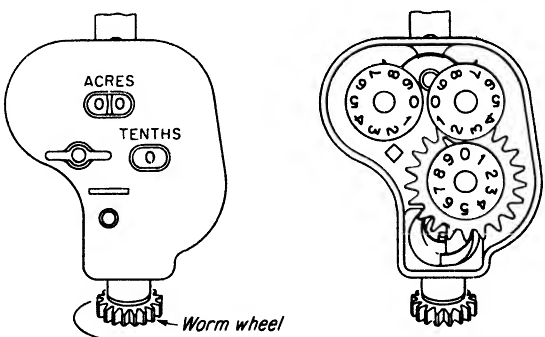


Fig. 12-45. Land measure or acre meter for grain drills.

have been turned the equivalent of ¼ or ½ acre, collect and weigh the grain. The weight of grain sown by each feed should be recorded separately so that each feed cup can be checked. To figure on an acre basis, multiply the amount by 4 if ¼ acre was selected and by 2 if ½ acre was sown.

If the indicator is set to sow 8 pecks, 8 pecks should also have been collected. If only 6 pecks of grain are collected, the drill is in error.

The percentage of error of the indicated quantity is calculated by dividing the difference between the quantity collected and the quantity the indicator was set on by the indicated quantity.

For example, the difference between the quantity collected and the quantity the indicator was set on in this case is 2 pecks. Dividing this by 8, the indicated quantity, gives an error of 25 per cent.

Furrow Openers. There are four types of furrow openers used on grain drills: the hoe, deep furrow, single, and double disk. A seed tube conducts the seed from the feed into the boot from which they fall into the

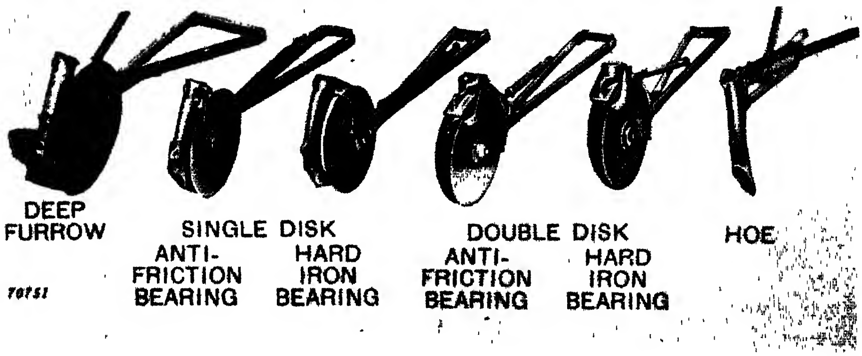


Fig. 12-46. Types of furrow openers for grain drills. (*Deere & Co.*)

furrow. Furrow openers are attached to the frame of the drill by drag bars (Fig. 12-46).

The *hoe* furrow opener consists of a single- or double-pointed shovel fastened to the lower part of the boot. The grain drops into the furrow directly back of the shovel. A spring or pin trip is provided so that, when the hoe strikes an obstruction, no damage is done. This type of opener often gives trouble by clogging up when used in trashy ground.

Single-disk furrow openers consist of one disk slightly dished, securely fastened to the boot, and set to run at a slight angle (Fig. 12-46). The seed are dropped from the boot on the convex side of the disk at a point below and to the rear of the center. A toe scraper is used on the convex side and a T scraper on the concave side to keep the disk clean. The single-disk opener gives good penetration, cuts trash well, and does not easily clog.

Single-disk semideep furrow openers have 14-inch single disks to open deep furrows in subhumid areas. Half the openers are assembled with the concave side facing to the right and half to the left. They can be set either staggered or in a straight line. Penetration is aided by spring pres-

sure. Since the disks revolve, they must be provided with bearings that are well designed, constructed, and lubricated. Some grain drills are equipped with a multi-lub system.

A *double-disk* opener is composed of two disks, having very little dish, set facing each other at a slight angle so as to form a bevel cutting edge where they penetrate the soil. In this position, the disks open a clean furrow and leave a small ridge in the center so that, when the seed are deposited in the furrow, there is a tendency to make two distinct rows about 1 inch apart. Saw-blade double-disk openers are designed to place the seed in the ground with the downward movement of the disks ahead of the disk axle. This type of opener is suitable for high tractor speeds and for trashy land.

A *lister* or *deep-furrow* opener is shown in Fig. 12-46. This type of furrow opener is used to make deep trenches or furrows and ridge the soil

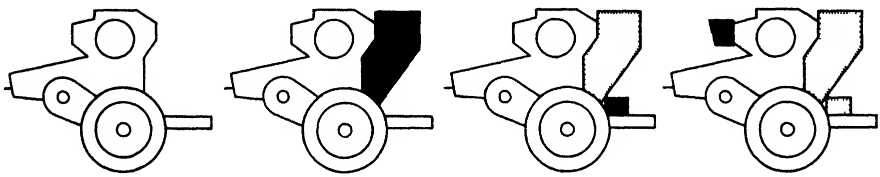


Fig. 12-47. End views of grain drills showing the general location of fertilizer and grass-seed attachments.

so that snow and moisture will be caught and the soil prevented from blowing. The spacing of the openers is wider than that used for the regular grain drill and ranges from 12 to 16 inches between openers.

Tractor Hitches. Where the ground is level and the acreage to be seeded is large, several grain drills can be arranged squadron fashion and hitched to one tractor. As many as five large drills can be hitched to the same tractor. A grain drill should be hitched to the tractor so that the frame and seedbox are level.

Attachments for Grain Drills. When a fertilizer attachment is used, the drill is usually known as a *fertilizer* drill, even though it is equipped with the regular grain-sowing feeds. The feed for distributing the fertilizer is shown in detail in Fig. 12-39. A special fertilizer tube serves as a spout to conduct the fertilizer down to the soil and prevents the wind from blowing part of it away. Liquid-fertilizer attachments are available for grain drills.

A grass-seeding attachment can be secured for almost all grain drills. It is attached either in front of or to the rear of the main seedbox, as shown in Figs. 12-39 and 12-47. The fluted-wheel type of feed is used in

the feed cups. The seed tubes may either empty directly into the regular grain-seed tube or be clamped to the side so as to allow the grass seed to fall behind the furrow openers.

The most common type of covering device is the drag chain. Figure 12-39 shows how it is hooked to the boot and how it drags over the furrows to cover the seed without packing the soil.

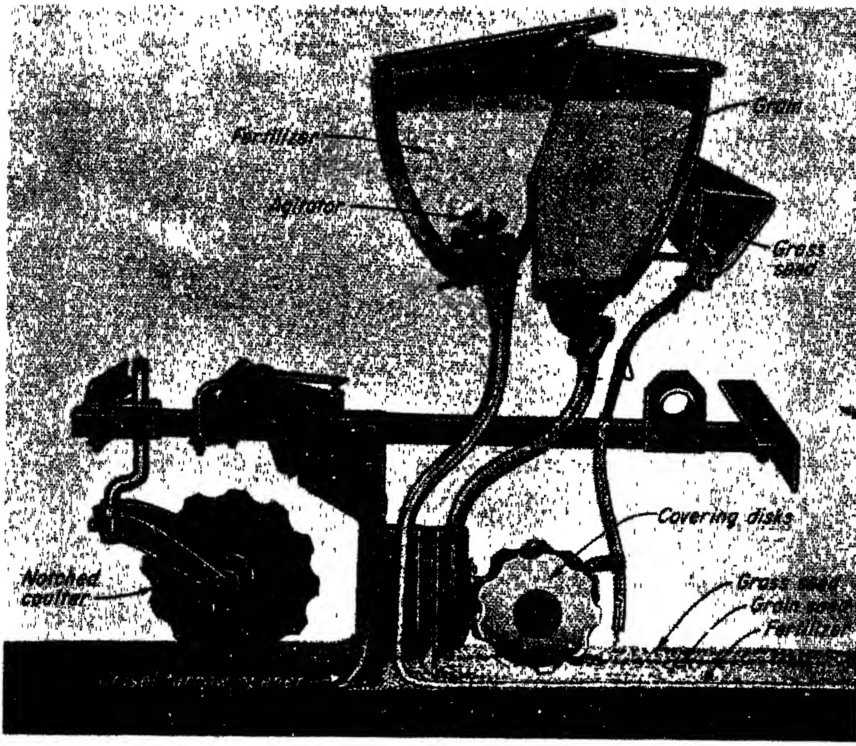


Fig. 12-48. Cross-sectional view of multiple-purpose or pasture drill showing how the grain and grass seed and fertilizer are placed in the soil. (*Deere & Co.*)

In the subhumid regions, where the soil is dry and likely to blow, press wheels are used to cover the seed and press the soil around them. Figure 12-37 shows a drill equipped with large press wheels. The latter also drive the seeding mechanism. Small gang press wheels also can be obtained.

Multiple-use Drills. Figure 12-48 shows a special-type drill, sometimes called a *grassland drill,* that is designed to open furrows in unplowed land; in growing crops, such as alfalfa; and in pastures. The seed are planted and fertilizer is applied as the furrow is opened. Thus, three op-

erations are performed simultaneously. Oats and other small grains and grass seed can be planted without first plowing, harrowing, and preparing the seedbed, as is necessary for the regular type of grain drill. If desired, fertilizer can be applied 3 or 4 inches below the surface in pastures without materially disturbing the established sod.

The furrow openers are usually spaced 8 to 10 inches apart. A sharp-edged, narrow chisel-type furrow opener is recommended for pasture lands.

Grass-sprig Planter. The grass sprigs are placed in a hopper provided with a feed device which feeds the sprigs into a rotating planting disc or wheel. The wheel passes through the hopper, picking up sprigs. As the wheel revolves, the sprigs are carried to the ground. The speed of the wheel is slightly less than the forward travel so that the friction of the soil pulls the sprigs from the "fingers" on the wheel, placing them in the soil. The soil is pressed together from the sides around the sprigs to hold moisture.

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QUESTIONS AND PROBLEMS

1. Enumerate fifteen factors that influence the germination of seed.
2. Explain the following: (*a*) drilling, (*b*) hill-dropping, (*c*) check-rowing, and (*d*) broadcasting.
3. Explain the field operation of a check-row planter.
4. Explain the function of the check wire in the operation of a check-row planter.
5. Discuss the differences in the dropping mechanisms for corn, sorghum, and cotton.
6. Give the advantages and disadvantages of the different types of seed furrow openers and explain the functions of press wheels.
7. What is meant by segmented beet seed?
8. Explain the differences in potato-dropping mechanisms.
9. Explain how the size of a grain drill is determined.
10. Name and explain the different grain feeds used on grain drills.
11. Describe how a grain drill is calibrated.
12. A 40-acre field of cotton is to be planted with a four-row central-mounted planter traveling at 5 m.p.h. The row spacing is 40 inches. Allow 75 per cent field efficiency for turns. The field is twice as long as wide. Calculate the time required to plant the field with the rows running the longest and shortest directions.
13. Explain minimum tillage.
14. Explain the terms plow-plant and wheel-track planting.

CULTIVATION AND WEED - CONTROL EQUIPMENT

13

The poet can weave beautiful words about the wonders of grass and how the world would go to ruin if there were no grass. But the farmer's classic words about grass and weeds would be far from poetic. It is true that the livestock producer does need grass and plenty of it, but the farmer who grows crops would be much happier if it were possible to confine all the grass and weeds to the pasture. The farmers of the United States spend billions of dollars annually in controlling weeds that compete with crops for plant food and moisture from the soil.

It has been said that weeds are robbers: they rob the farmer of his profits by reducing yields, they rob by lowering the quality of the crop, they rob the farmer by harboring insects that damage his crop, they rob by reducing the land value, and they may become so thick that the crop has to be abandoned, so that they could rob the farmer of his home. Therefore, the farmer must fight to control weeds with every means he can command. The farmer's primary tools of war on weeds are (1) cultivation by stirring the soil, (2) the use of flame, and (3) the use of chemicals.

CULTIVATORS

Cultivation is an operation that requires some kind of tool that will stir the surface of the soil to a shallow depth in such a manner that young weeds will be destroyed and crop growth promoted. Cultivation to con-

trol weeds by stirring the soil may start on the prepared seedbed prior to planting. After planting, the soil can be cultivated before emergence of the plants for some crops. Cultivation usually begins soon after emergence of the young crop seedlings, as weeds generally emerge about the same time as the crop.

History of Cultivator Development. The first implement used for the control of weeds in crops was, perhaps, the hoe. In ancient times, most crops were planted broadcast, and the hoe was about the only tool that could be used to destroy weeds among the plants. Many Asiatic countries, even today, do not have hoes and weeds are pulled from rice paddies by hand

When crops were planted in rows, the plow could be used to destroy the weeds between the rows and throw soil over the young weed seedlings in the crop row, which smothered them to death. The single-shovel plow was changed to a double-shovel so that half the space between two crop rows could be stirred for weed control.

The next advancement in cultivation equipment was a V-shaped wooden frame to which wood or iron pegs were attached. Handles permitted the operator to control the tool manually. Early in the eighteenth century, Jethro Tull[1] invented the horse hoe. Davidson[2] states that "A patent was granted to George Esterly, April 22, 1856, on a straddle-row cultivator for two horses . . . ." Horse-drawn one-row walking and riding cultivators came into use in the late 1880s. The two-row riding horse-drawn cultivator came into use shortly after 1900. The first row-crop cultivators used with tractors were horse-drawn cultivators adapted for hitching behind the tractor.[3] The B. F. Avery Company built a tractor-mounted cultivator about 1918. The first integral-mounted cultivator attachment for tractors was developed about 1925 by the International Harvester Company. The gangs were lifted by manually operated levers.[4] Power lifts for cultivators were not developed until about 1932 or 1933.

Objectives of Cultivation. The primary objectives sought in the cultivation of a crop are:

1. Retain moisture by
   a. Killing weeds
   b. Loose mulching on surface
   c. Retaining rainfall
2. Develop plant food
3. Aerate the soil to allow oxygen to penetrate soil
4. Promote activity of microorganisms

[1] Jethro Tull, *Horse Hoeing Husbandry*, 1822.

[2] J. B. Davidson and L. W. Chase, *Farm Machinery and Motors*, Orange Judd Publishing Co., Inc., New York, 1912.

[3] F. R. Jones, Large Scale Farming, *Tex. Agr. Expt. Sta. Bul.* 362, 1927.

[4] First picture shown in article by D. W. Watkins, Use of Machinery in Cotton Production, *Agr. Engin.*, 7(10):349, 1926.

Many types of cultivators are in use, ranging all the way from the small hand-pushed garden cultivator suitable for the family garden to large eight-row tractor-mounted cultivators capable of cultivating 100 to 130 acres per day (Fig. 13-1). The type and size needed will depend upon the acreage, the kind of crop, soil type and conditions, rainfall, type of farming practiced, and the kind of power available.

As tractors have largely supplanted horses and mules for farm power, only the tractor types of cultivators will be discussed. Most row-crop cultivators are mounted on tractors centrally but well forward. Tractors equipped with the three-point linkage hitch are usually provided with an

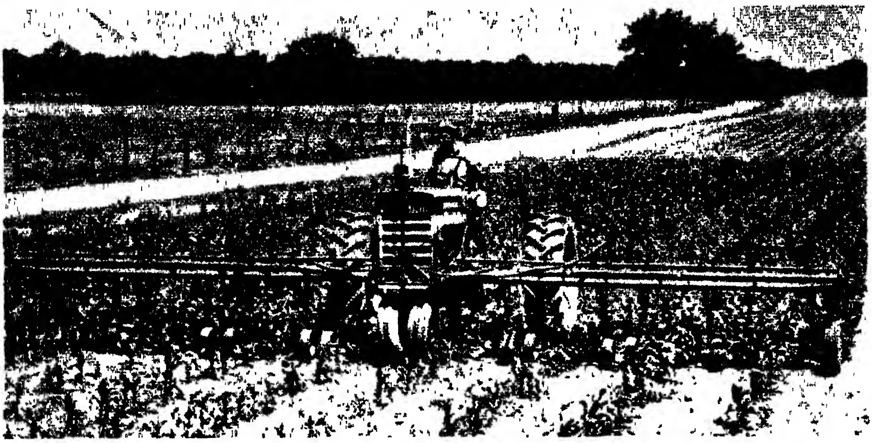

Fig. 13-1. Front-mounted eight-row hydraulically lifted cultivator cultivating corn. (*International Harvester Company.*)

assembly cultivator unit that operates behind the tractor. Cultivating equipment for track-type tractors is either mounted in front of or to the rear of the tractor.

Central-forward Tractor-mounted Cultivators. Central-forward-mounted cultivators are available in one-, two-, four-, six-, and eight-row sizes. Cultivator units can be mounted on both the four-wheel and the three-wheel or tricycle-type tractors. The one-row cultivator mounted on the one-plow-sized tractor is suitable for small farms and terraced fields with curving rows. The two-row cultivator is suitable for medium-sized farms and fields that have rows either straight or with gradual curves. The four- to eight-row cultivator is suitable for large farms and level land where the rows are straight for long distances. All sizes can be used on either flat or bedded land but are not adapted for use in the listed furrow. The gangs are hydraulically raised and lowered and in some cases controlled for depth of cultivation.

The older style tractor-mounted planters and cultivators required several hours' labor to change from planting to cultivating equipment. Designers have devoted much thought to the design of equipment that can be changed quickly and easily. Therefore, most of the more recently designed cultivators are first assembled into three units: one unit for each forward side of the tractor and one rear-section unit. Figure 13-2 shows

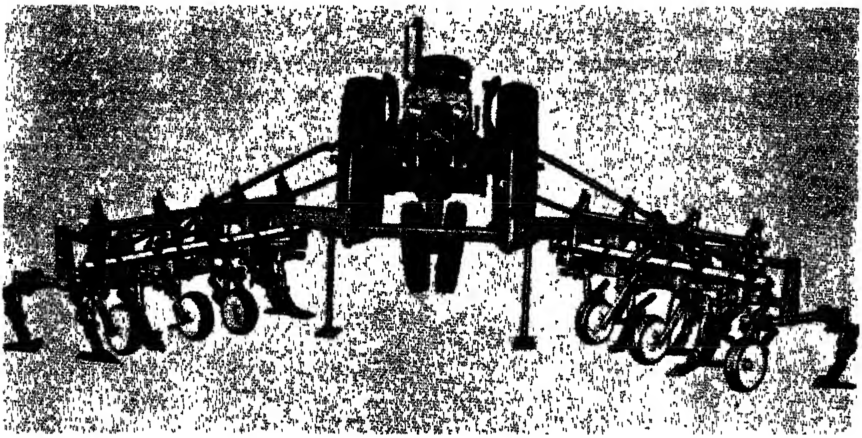

Fig. 13-2. Front-mounted cultivator units in position for attaching to the tractor.

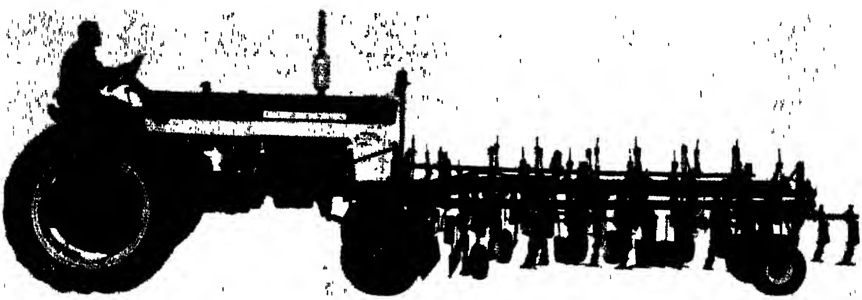

Fig. 13-3. Method of folding an eight-row cultivator for transportation. (*International Harvester Company.*)

a tractor being driven into position for the mounting of the two forward units of a large cultivator. To mount the rear section, the tractor is backed up to it and the attaching brackets or pads are slipped onto bolts accurately positioned. Figure 13-3 shows an eight-row front-mounted cultivator folded for transportation. Semipneumatic or rubber-covered gage wheels support the individual gangs to give uniform depth of cultivation. The rear section shown in Fig. 13-4 consists of three gangs or rigs to

carry three sweeps which loosen the soil behind the tractor wheels to prevent soil compaction and leave a smooth middle.

Gangs for Cultivators. The gang or rig consists of a beam to which is attached a shank or standard that has an adjustable foot set at an angle so a shovel or sweep can be bolted to it. There is a gang for each side of each row. A single-row cultivator has two gangs, a four-row cultivator eight gangs, and an eight-row cultivator has sixteen gangs. There are numerous types of gang assemblies designed to suit different crops, soils, and farming practices. The number and type of soil-stirring members usually determine the gang style.

The *beam* may consist of a straight pipe, a shaped square bar, or a fabricated beam of flat bar steel. A pipe beam requires crossheads to sup-

Fig. 13-4. Rear gangs of cultivator equipped with sweeps to plow out tractor tracks and loosen the soil in the wheel tracks. (*International Harvester Company.*)

port the shanks so the soil-stirring members can be adjusted laterally as the number of shanks and size of the sweeps vary. The square bar beam is bent laterally so the shanks can be clamped directly to the bar. The fabricated bar beam is shaped to permit clamping of the shanks at the desired positions.

Under severe conditions, the gangs are held apart a uniform distance by space bars, arches, or hobbles.

The gangs can be moved laterally on the frame bar to suit various row spacings. When the bolts are tight, the gangs are held solidly in place. No provision is made for shifting the gangs sidewise other than the regular steering of the tractor.

The rear section of a tractor-mounted cultivator consists of three beams, shanks, and sweeps. A sweep is set so that it will loosen the soil in each of the three middles behind the tractor wheels of a three-wheel tractor (Fig. 13-4). These sweeps are often termed *plow-out* sweeps, as they plow out the tracks made by the tractor wheels.

Three types of *shank trips* or *releases* are available for use in areas where rocks and roots are present in the surface soil. They are the *spring-*

trip, break-pin, and *friction* (Fig. 13-5). Where there are no hidden obstacles in the soil, a solid, round-rod steel shank can be used. The rigid shank is used for *disk hillers* and *barring-off* disks.

Lifts for Cultivator Gangs. The gangs of the first tractor-mounted cultivators were lifted with hand levers. Later, gear-operated rocker arms were attached to the tractor and connected to the gangs by a linkage arrangement so the gangs could be power lifted. All gangs on the cultivator were lifted at the same time.

Hydraulic power lifts are now used to lift all arrangements of cultivator gangs on all sizes and makes of field tractors. The use of delayed lift valves and other hydraulic-control features makes it possible to lift

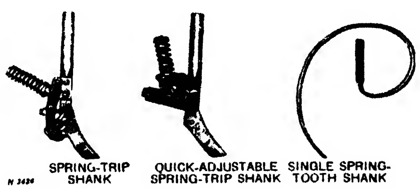

Fig. 13-5. Types of cultivator shanks. (*Deere & Co.*)

the gangs on each side of the tractor separately and at different time intervals. This is helpful in cultivating point rows on terraced fields. The rear section is lifted and lowered slightly later than the front gangs to permit plowing out to the end of the row. Then the delayed lowering prevents the sweeps from entering the soil and tearing up headlands because the tractor moves forward a few feet before the rear gangs are lowered.

Shovels and Sweeps. There are numerous types and shapes of shovels and sweeps used for stirring the soil and killing weeds, as shown in Figs. 13-6 and 13-7. Shovels are available in widths up to about 3½ inches (Fig. 13-6), but sweeps can be obtained in widths ranging from 6 to 24 inches. The width or size is in even inches, such as 6, 8, 10, 12, and up to 24 inches. The types of soil, crops, and weeds influence the shovel or sweep used. The sweeps designed for horse-drawn cultivators throw too much soil and cover small plants when used at high speeds on a tractor. New designs of high-speed sweeps have the crown[5] and wings set fairly flat to skim under the soil at a shallow depth without throwing excessive amounts of soil (Fig. 13-8). The ASAE[6] has set up standards and specifications for curved and straight stemed sweeps.

[5] The crown is the rounded area of the sweep between the wings and lower part of the sweep shank.

[6] Cultivator Sweep and Shovel Mountings, *Agr. Engin. Yearbook,* 1962.

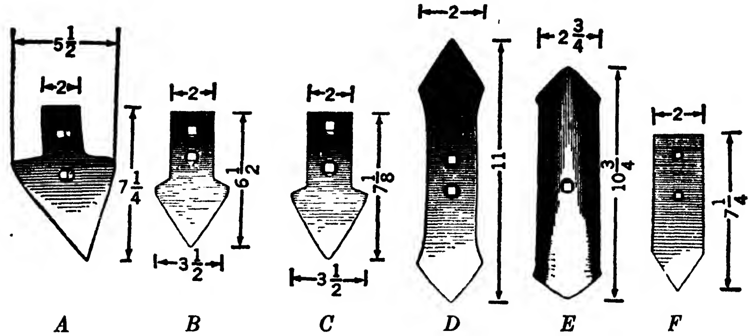

Fig. 13-6. Types of shovels for cultivators: *A*, spear point for sleeve; *B*, single point for spring tooth; *C*, single point for sleeve; *D*, double reversible point for spring tooth; *E*, double reversible point for sleeve; *F*, single point for spring tooth.

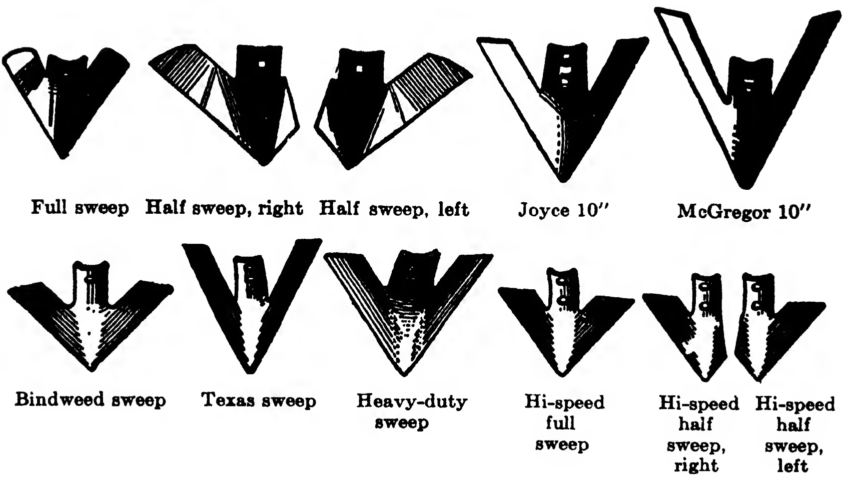

Fig. 13-7. Types of sweeps for cultivators.

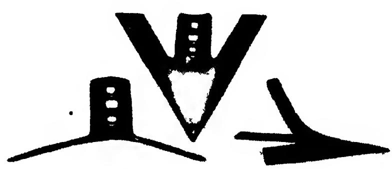

Fig. 13-8. Front, rear, and side views of a high-speed sweep.

Shovels and sweeps should be operated as shallow as possible to prevent pruning the roots from the crop plants and thereby injuring the plants. Sweeps should be set almost flat. When the point is resting on the floor or ground, the outer tip of the wing should be elevated only 1/8 to 1/4 inch above the floor (Fig. 13-9).

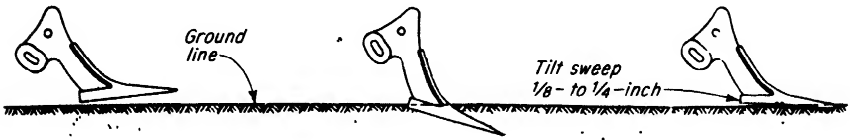

Fig. 13-9. Wrong and correct settings for a cultivator sweep.

Most tractors have sufficient power and gear ratios to operate cultivators at speeds slightly better than 5 m.p.h.

The shovels and sweeps should be set equal distances on each side of the row to keep the land well shaped, aiding in later cultivations and in the harvesting operation. They can be set uniformly before going to the field by using a line diagram on the floor (Fig. 13-10) or an implement-

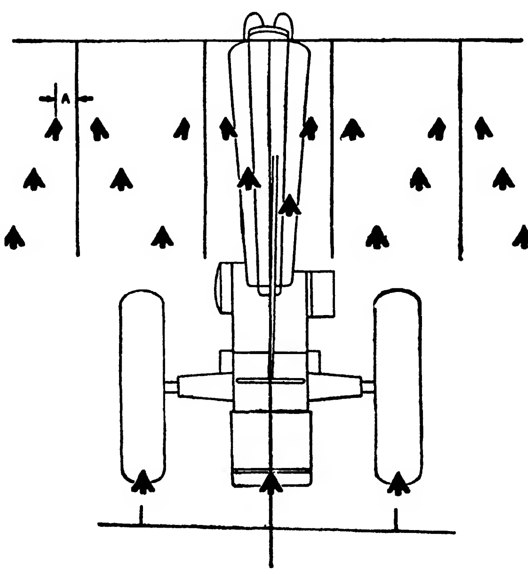

Fig. 13-10. Line diagram for setting the sweeps on a four-row tractor-mounted cultivator. Mark heavy lines on the floor at the desired row spacing.

setting frame (Fig. 13-11). The lines are drawn for the row spacing desired, and the frame can be adjusted for any row spacing. The lines and frame can be used for setting the rear cultivator section and other rear- and front-mounted equipment.

Attachments for Central-forward-mounted Cultivators. In addition to the regular gang equipment that makes up the basic cultivator unit, there are

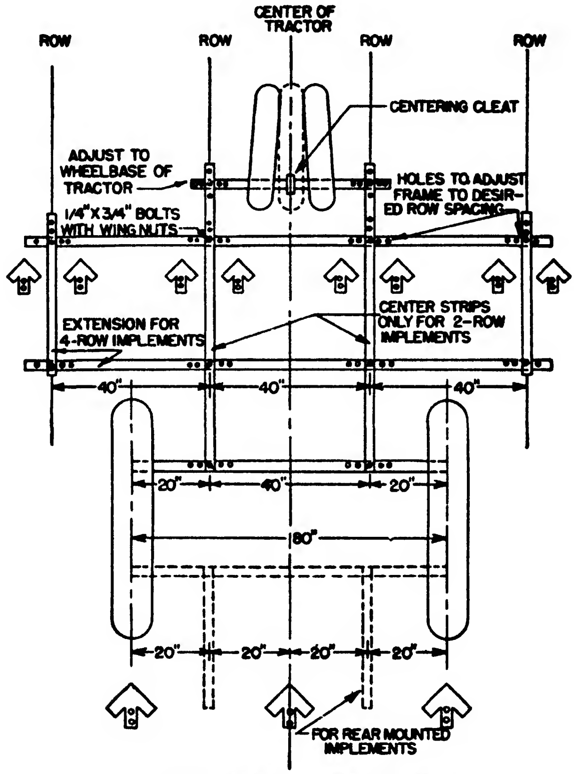

Fig. 13-11. Frame for setting cultivator sweeps and other tractor-mounted equipment. The frame is built of light material. (*Texas Agricultural Experiment Station.*)

a number of special-purpose attachments that add to the usefulness and improve the performance of a cultivator. A number of tractor-cultivator attachments are shown in Figs. 13-12 to 13-15.

The *rotary-hoe* attachment for tractor cultivators (Fig. 13-12) is a popular and useful attachment for breaking the soil crust over emerging plant seedlings and for destroying weeds in the early stages of plant growth. It is used on most of the row crops. The hoe wheels or spiders

Fig. 13-12. Rotary-hoe attachments for tractor cultivators.

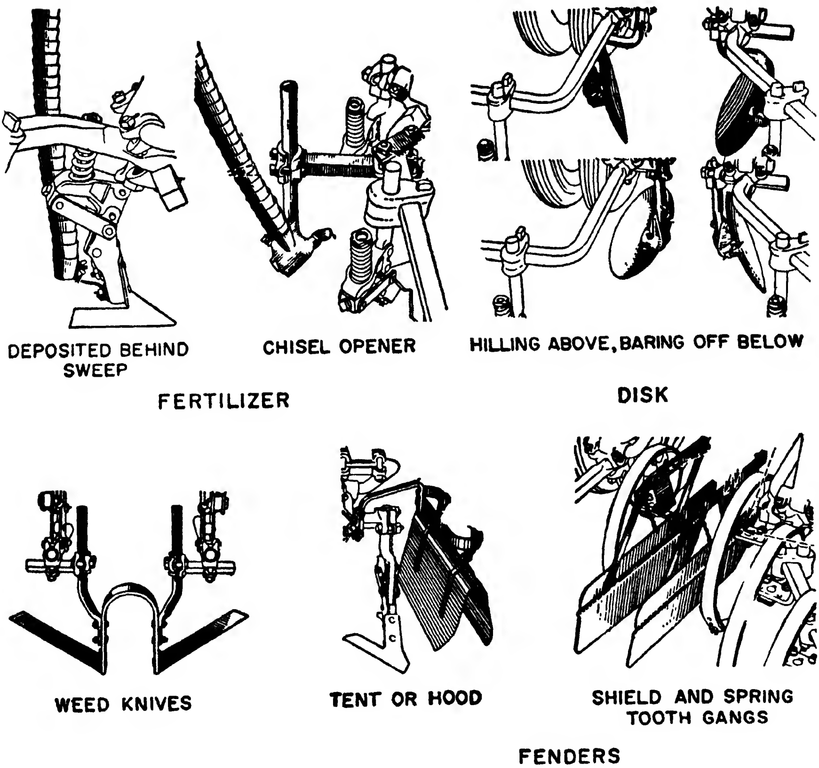

Fig. 13-13. Fertilizer, disk, knife, and fender attachments for tractor-mounted cultivators.

are mounted between the front shovels or sweeps. The *tines* of the wheel project into the soil for from 1 to 2 inches directly over the plants. Flakes of soil crust are flipped up, and young annual weed seedlings are uprooted and killed. Young weeds are uprooted better if the rotary hoe is used after a soil crust has formed. Best results are obtained when the rotary hoe is operated at speeds of 5 m.p.h. or faster. Rotary-hoe attachments can be used on bedded land, on flat land, and in the listed furrow.

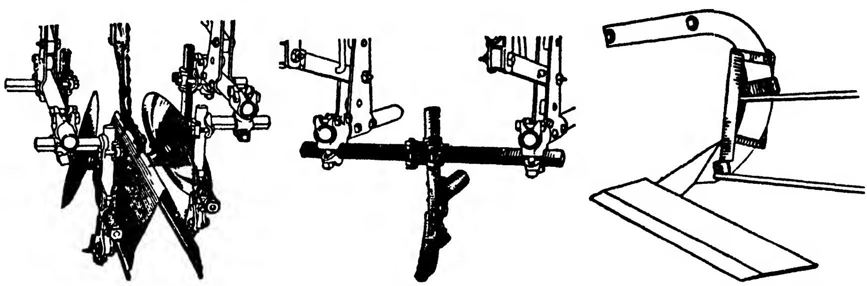

Fig. 13-14. Listed corn, spread-bar, and peanut-digger attachments for tractor cultivators.

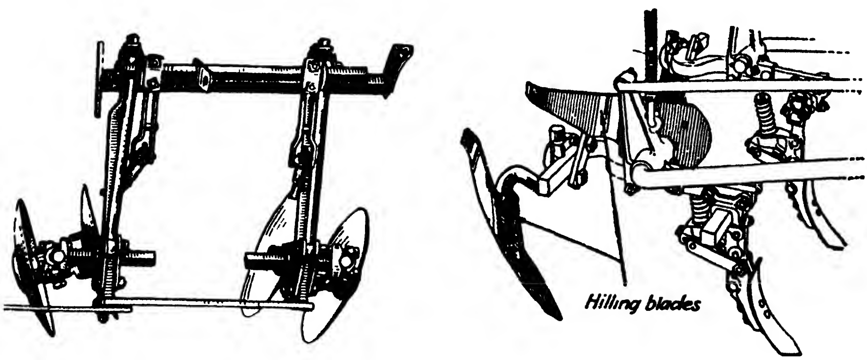

Fig. 13-15. Disk-gang and potato-hilling attachments for tractor cultivators.

Two methods of applying fertilizer as a side dressing by the use of fertilizer attachments are shown in Fig. 13-13. In one method, the fertilizer is deposited behind the front sweep which is next to the row. The soil thrown by the rear sweeps on the gang covers the fertilizer. In the other method, a narrow chisel opener opens a narrow furrow to the desired depth and the fertilizer flows through the tube and boot into the furrow. An adjacent sweep throws soil over the furrow to cover the fertilizer. The types of fertilizer feed and hoppers used are discussed under Fertilizing Equipment.

Disk-hilling and *barring-off* attachments are shown in Fig. 13-13. For hilling, the disks are set to throw the soil to the plant row. Where the crop is quite grassy, the disks are set to throw the soil away from the plant row. This leaves only a narrow strip to clean with the hoe.

The *knife* attachment shown in Fig. 13-13 is used as a barring-off tool, but it does not leave an open furrow as do the disks.

Fenders are used between the cultivator sweeps next to the plant row to prevent soil from covering small young plants. The *tent* or *hood* type allows soil to be thrown up on the fender so it will flow off the rear end and settle around the plants without covering them. The *blade* fenders hold the soil away from the plants. A *rotary-hoe wheel* or *spider* set to run on each side of the row, as shown in Fig. 13-12, also acts as a fender. It lets a small amount of soil shift through the tines and flow around the plants, but at the same time it prevents large masses and lumps of soil from being thrown over them.

Listed-corn, *spread-bar*, and *peanut-digger* attachments for tractor cultivators are shown in Fig. 13-14.

Disk-gang and *blade potato-hilling* attachments for cultivators are shown in Fig. 13-15. Disk gangs on cultivators are often used in extremely sandy soils.

Rear-mounted Cultivators. Rear-mounted cultivators are usually unit assemblies attached to four-wheel tractors equipped with a three-point hitch (Fig. 13-16). The units may have either stiff or flexible spring-tooth shanks attached to a box-frame tool bar. The frame has a front and rear tool bar which permits the equal-length shanks to be arranged in a staggered pattern and spaced to straddle rows of plants. The shanks can be moved laterally along the frame for different row spacings. Figure 13-17 shows a rear-mounted narrow-row cultivator for row spacings from 22 to 28 inches.

Speed and Duty of Cultivators. The average speed of horse cultivation is usually given as 2.5 m.p.h. When cultivators were first mounted on tractors, many operators used low gears or less than a full-throttle setting to hold the speed down to 2.5 to 3.0 m.p.h., feeling that they could do a better job of weed control. There are still many farmers who operate their tractors at relatively slow speeds, even though the tractor has ample power for faster operation.

With rotary-hoe attachments and high-speed sweeps, it is more economical to operate the tractor at the higher speeds than at the lower speeds, as it reduces both labor and tractor hours.

Special Cultivating Equipment. In addition to the regular cotton and corn types of cultivating equipment, there are several types of cultivators designed for special crops and conditions.

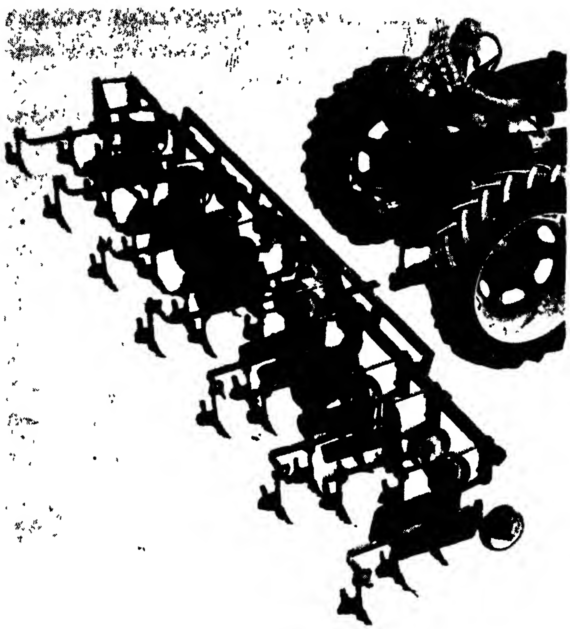

Fig. 13-16. Six-row quick-attachable rear-mounted cultivator. (*International Harvester Company.*)

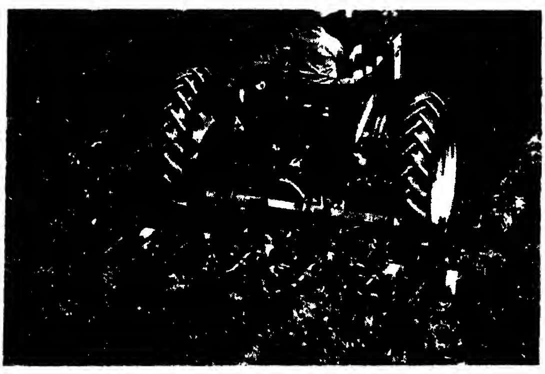

Fig. 13-17. Six-row narrow-row cultivator for 22- and 28-inch row spacings. (*International Harvester Company.*)

Beet and Bean Cultivators. Beets and beans are usually planted in more closely spaced rows than cotton and corn and require shovels and sweeps for shallow cultivation. Gage wheels control the depth of penetration of the shovels. The weed-knife shanks are attached to tool bars and can be adjusted for row widths ranging from 12 to 28 inches. The tool bar can be mounted either centrally (Fig. 13-18) or on the rear of the tractor.

The sizes of beet and bean cultivators range from two to six rows, the four-row being the most popular size. Attachments are available for the application of fertilizer as a side dressing.

Lister Cultivators. Lister cultivators are particularly adapted to the cultivation of a listed crop in its early stages of development. Listed crops are those planted in the furrow or trench or below the general level of

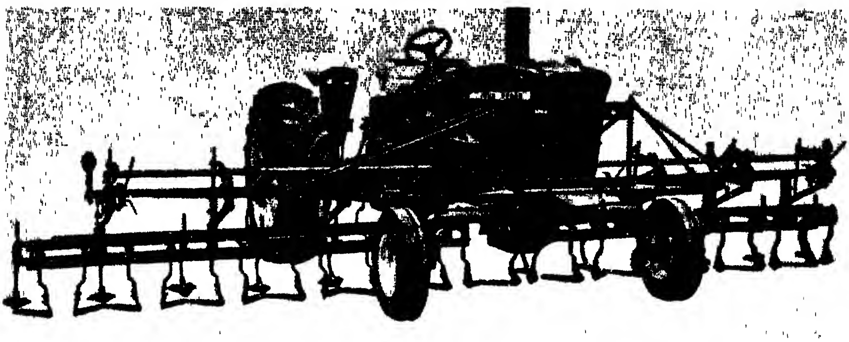

Fig. 13-18. Beet and bean cultivator. (*Deere & Co.*)

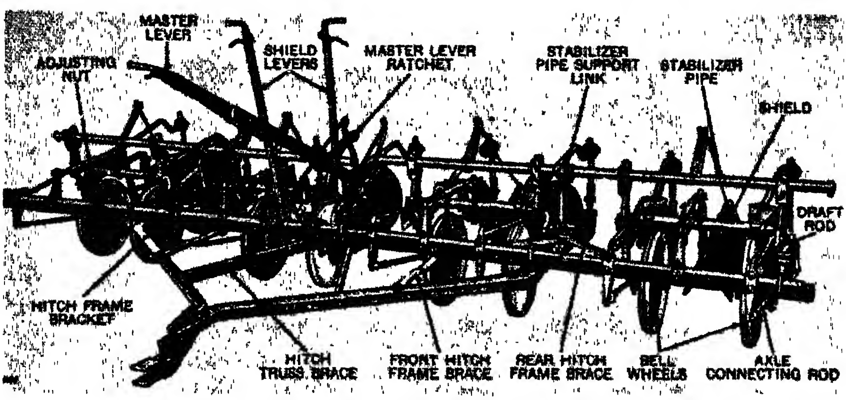

Fig. 13-19. Four-row trailing-type lister cultivator. (*Deere & Co.*)

the ground. The four-row tractor-drawn listed-furrow cultivator, shown in Fig. 13-19, has wheels to support and guide the gangs for each row. For the first cultivation, the disks are set to throw the soil away from the row of plants. For all later cultivations, the disks are set to throw the soil toward the plants.

Rod Weeders, Field Cultivators, Subsoil and Chisel Cultivators. These cultivators are generally used to control weed growth on fallow lands and are discussed under Secondary Tillage Equipment.

Rotary-hoe Cultivator. The rotary hoe is a cultivating implement used to cultivate and destroy weeds and grass around young plants. When rains cause a hard crust to form over the soil and hinder the emergence of young seedlings, the rotary hoe is an excellent tool for pulverizing the crust. The tool can be used to advantage in young corn, cotton, soybeans, potatoes, and small grains.

The rotary hoe is made up of two gangs of hoe wheels. One gang is placed behind the other, and the wheels are spaced so that the wheels of the rear gang extend forward between the wheels of the front gangs. Some two- and three-row units have solid axles, while the larger units for

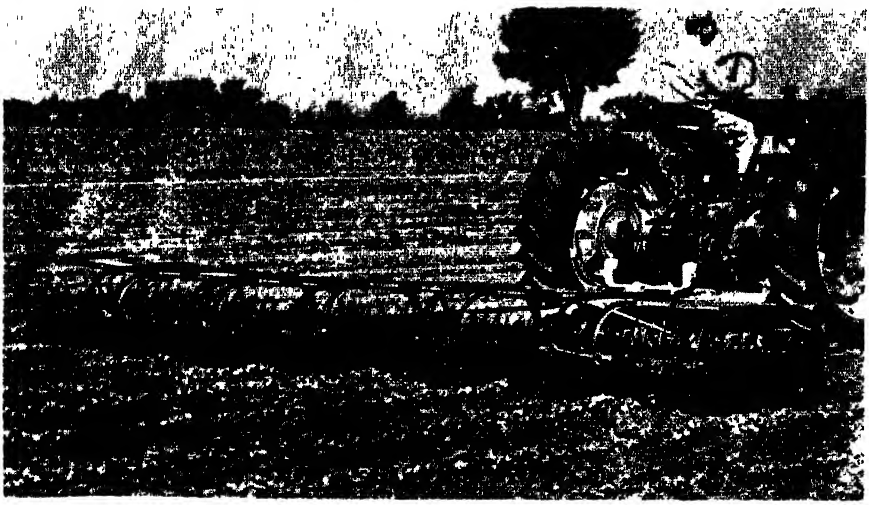

Fig. 13-20. A six-section trailing rotary hoe can be used to cultivate young cotton, corn, and soybeans. (*International Harvester Company.*)

tractor use are made up in sections so that each section can follow the contour of the soil (Fig. 13-20). The hoe wheels or spiders are usually made of malleable cast iron, but fabricated-steel wheels are also available.

Rotary hoes should be used at fairly high rates of speed. Good work can be done under some conditions at 10 m.p.h. If the plants are large, there is a tendency for the tines to catch the foliage and pull up a few plants.

When a rotary hoe is run backward or with tines reversed, it makes a useful tool as a *treader* to tread down heavy stubble and other crop residues without clogging. It tears apart large clods, packs the soil from below, and at the same time treads the seed into the clean, firm seedbed through the protective residue which may be on the surface. It also becomes a good broadcast seeder when a seeder box is attached. Figure 13-21 shows a tractor-mounted rotary hoe.

Figure 13-22 shows a tractor-mounted frame to which are attached three five-spider gangs of rotary hoes per row. The front gangs are set so that the spiders roll directly over the row of plants. The rear gangs can be angled to conform to the slope of the sides of beds. They can be set to throw the soil to or away from the plants. They can be reversed so the curved spider tines act as treaders.

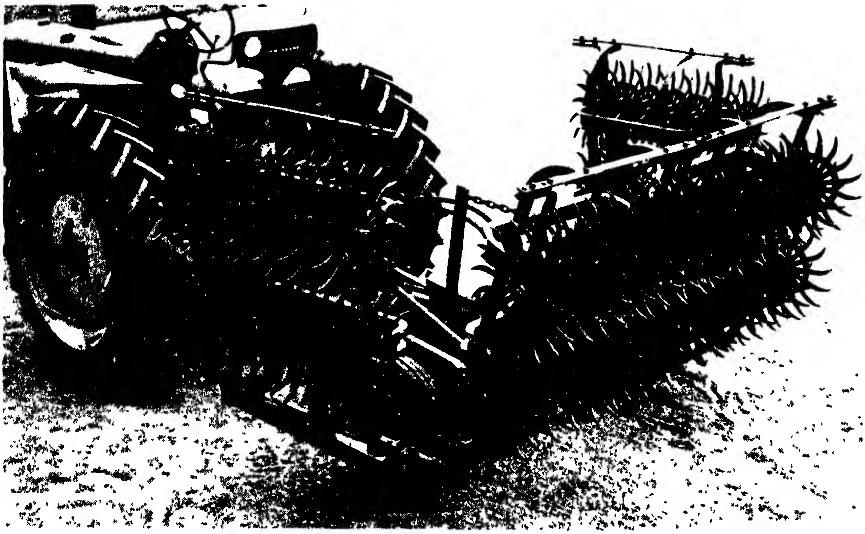

Fig. 13-21. Tractor-mounted rotary hoe in raised and folded position for transportation. (*Deere & Co.*)

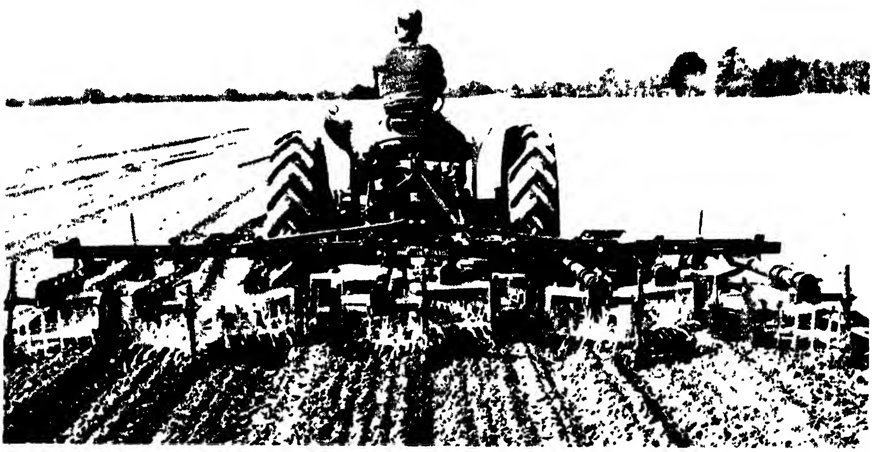

Fig. 13-22. Gangs of rotary hoes attached to pipe beams with swivel joints so the gangs can be angled and reversed. (*Lilliston Implement Co.*)

Plant-thinning Machines. When the seeds of cotton, beets, and other crops are drilled thick along the row to get good stands, it is sometimes necessary that the plants be thinned to obtain the best yields. A cutterhead for thinning cotton consists of four knives clamped in a hub. The knives can be turned and adjusted to leave an uncut space along the row from 1½ to 5 inches (Fig. 13-23). Different-sized sprockets are provided

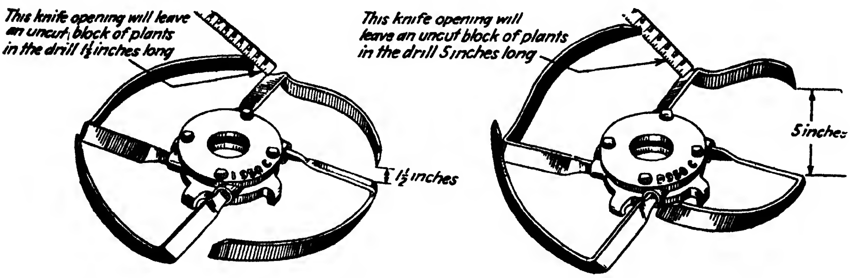

Fig. 13-23. Rotary plant thinner. The space between toe and heel of the blades can be adjusted from 1½ to 5 inches.

Fig. 13-24. Swinging blade plant thinner.

to vary the speed of the cutterhead and the spacing of the hills. Single- and two-row trailing machines are made. Straight spikes can be substituted for the knives to knock out grass from among the plants.

The plant thinner shown in Fig. 13-24 is centrally mounted on the tractor. Knives are mounted on ends of two suspended bars that swing back and forth across the row of plants. The tractor is moving forward as the knives swing across the row. A diamond-pattern space is left uncut.

Figure 13-25 shows a plant thinner that has a rimless wheel of L-shaped flat steel bars. The short leg of the L-shaped bar presses on the ground, while a gear-driven inner angled wheel of synchronized knives cuts across the row between the L-shaped feet.

Fig. 13-25. A plant thinner that has a rimless wheel of L-shaped flat steel bars that press on the ground while a gear-driven angled wheel of synchronized knives cuts across the row between the L-shaped feet. (*Blackwelder Mfg. Co.*)

Plants also are thinned and blocked by the use of sweeps set flat and run at right angles or across the row. This is called *cross plowing.*

FLAME WEED CONTROL

Flame has been used by railroads for many years to kill weeds. It has also long been used by ranchmen to burn the spines off cactus so that livestock could graze on the cactus during long droughts. The use of flame for the control of grass and weeds among row-crop plants is a comparatively new development. The equipment consists of a fuel tank, feed lines, control valves, and burners. The system is mounted on a tractor with skid supports for the burners (Fig. 13-26). Burners are provided for each side of each of two to four rows. A two-row system requires four burners, and a four-row system requires eight burners. The burners are mounted at about a 30- to 45-degree angle with the horizontal so that they will direct a hot, blue flame close to the ground on the grass among the plants. The flame should strike the ground about 2 inches from the plant on the burner side. The width of the burner mouth should be 8 to

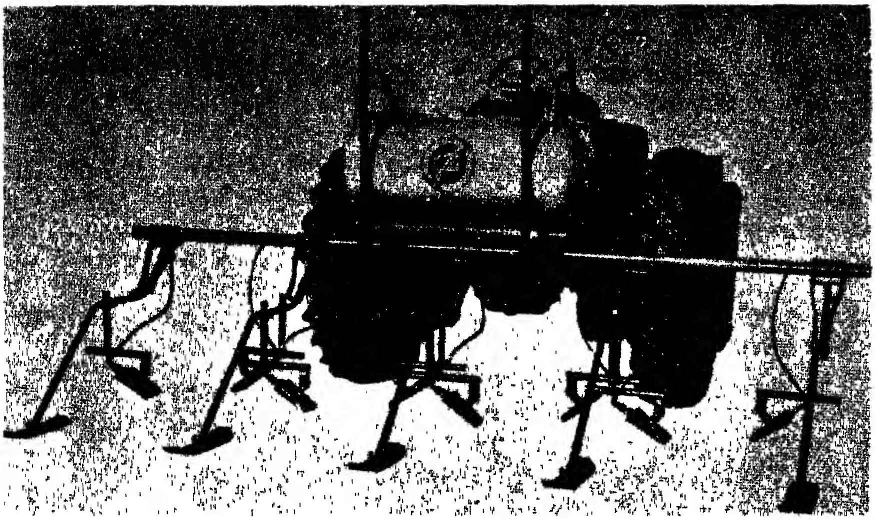

Fig. 13-26. Flame burners mounted on brackets supported by skid shoes. (*Gotcher Engineering & Mfg. Co.*)

Fig. 13-27. Flame burners mounted on the regular cultivator gang. (*Mississippi Agricultural Experiment Station.*)

10 inches. Plants to be cultivated should be tougher and larger than the grass and weeds to be destroyed. The burner is provided with both vertical and horizontal adjustments.

Most flame burners are mounted on brackets supported by skids, but good results have been obtained by mounting them on the regular cultivator gangs (Fig. 13-27). The burners should be mounted so that the

flame of one burner does not meet the flame on the opposite side of the row (Fig. 13-28). This is termed across-the-row flaming. Recent research shows some advantages in the early stages of plant growth to setting the burners so the flame will be directed parallel to and alongside the row of plants.

Either butane or propane can be used for fuel for flame weeders. The fuel is carried in a high-pressure tank mounted on the tractor. The tank is fitted with control valves and fuel-line connections. The pressure on the fuel line leading to the burners may range from 30 to 40 pounds. If the

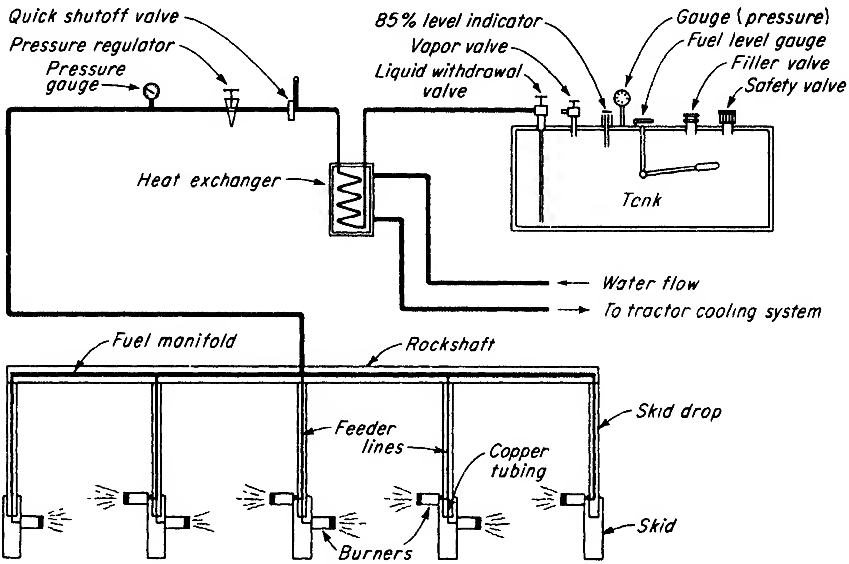

Fig. 13-28. Schematic diagram of a flame method of weed control.

grass and weeds are dense and more than an inch in height, the tractor should be driven at the comparatively slow speeds of 2 to 2½ m.p.h. But if the weed seedlings are young and fairly thin, the tractor can be operated around 3 m.p.h.

CHEMICAL WEED CONTROL

The use of chemical herbicides for the control of weeds in crops is a relatively new development. In some broadcast crops, such as wheat and rice, the chemical used is selective. This means that the chemical will kill the weeds and not kill the growing crop plants. Some chemicals used on row crops must be applied in such a way that the chemical does not come in contact with the crop plants, or the plants will be injured or

killed. Some herbicides are toxic to human beings and should be handled with all precautions to prevent injury to operators.

Commercial row-crop herbicides are classified as *pre-emergence* and *post-emergence*, according to the time of application and mode of action. The pre-emergence chemicals are applied after planting but before the crop plants emerge above the soil. The post-emergence chemicals are applied after the crop plants have emerged. The plants must be allowed to obtain sufficient growth so the chemical spray can be directed on the young weed seedlings but below the foliage of the plants.

Pre-emergence Applications. Several chemicals are used as pre-emergence herbicides. Formulations of dinitro-*o*-secondary-butylphenol have shown

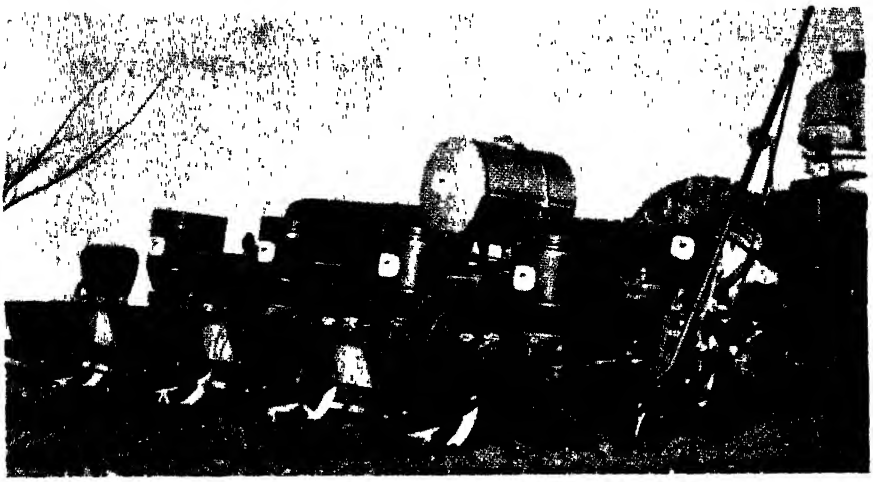

Fig. 13-29. Four-row planter equipped with press wheels, pre-emergent spray hose, and nozzles. (*Deere & Co.*)

encouraging results. Other compounds used are Diuron and Trifluralin or "Treflan" the trade name. The manufacturer's label gives instructions and cautions for the use of these materials under varying conditions.

To obtain the best results with pre-emergence herbicides, it is essential that plant residues from previous crops be thoroughly disposed of or removed. The seedbed should be well prepared so that the drill area will be left as smooth as possible behind the planter. The drill area or row should be slightly higher than the middle to prevent soil containing weed seed from being washed, blown, or pushed onto the treated area. A press wheel or roller 12 to 14 inches wide should be mounted behind the planter furrow opener to smooth and firm the soil to be sprayed. A regular spray rig is mounted on the tractor in conjunction with the planter. A spray nozzle is mounted to the rear of the press wheel or roller (Fig. 13-29). The mounting for the nozzle should be adjustable both vertically

and laterally. A low-gallonage nozzle that gives a fan-shaped spray pattern is best for pre-emergence application of herbicides. The nozzle orifice should be constructed to give a wide fan-shaped spray of 80 or 95 degrees with a pressure of 25 to 40 pounds.

The best results with pre-emergence chemicals have been obtained where the spray has been applied on the moist soil directly behind the press wheel or roller. The frequency of rains should be such that rain will occur between the time of planting and emergence to seal the chemical in the surface soil. Where rain does not occur until after emergence of the crop, the raindrops will spatter the loose soil and chemical up onto the young seedlings and damage is likely to occur. The chemical in the top 1/8 inch of the soil prevents annual weed seeds from germinating for a period of 2 to 3 weeks.

Post-emergence Applications. Post-emergence herbicides for cotton consist mostly of the nonfortified oils formulated especially for use in cotton. Other compounds, such as dinitro selectives, CIPC, and derivatives of 2,4-D (2,4-dichlorophenoxyacetic acid), can be used as post-emergence sprays for corn, grain, and certain grass crops.

For Cotton. The National Cotton Council of America in a 1961 *Progress Report* states that:[7]

> Certain herbicidal oils may be used as the principal method of post-emergence weed control, whether or not preemergence application has been made. They may also be used in conjunction with flame cultivation. Regardless of treatment, effective control requires application of herbicidal oil when weed seedlings first appear in the drill area. Timeliness of application is basic to the success of post-emergence control. Most weeds less than two inches high are controlled easily, but larger weeds are difficult to control.
>
> Herbicidal oils should be applied by means of directional spray equipment. The flat, fan-shaped spray patterns should be directed across the area to be treated in a horizontal manner at a height of one inch or less from the ground level. Two nozzle tips are used per row, one on either side. They should be set about 10 inches apart and staggered to prevent interference in the spray pattern [Fig. 13-30].

It is usually possible to cultivate the middles and shoulders with appropriate ground-working tools at the same time the post-emergence herbicides are being applied. Herbicide chemicals are used at the last cultivation of the crop to control weeds and grasses from lay-by to harvest.

Isolated Johnson grass plants can be eradicated by spot spraying with dalapon or TCA. The spraying can be done with a knapsack or hand guns attached to a long hose from a tractor- or trailer-mounted sprayer.

[7] Cotton Pest Control Guides, Official Recommendations for 1961, National Cotton Council.

As the spray nozzles must be supported within 1 inch of the soil surface and the foliage of the cotton plants must be protected, special applicator shields or shoes are required (Fig. 13-31). The shield supports the spray nozzle and protects the treated drill area from soil thrown by the sweeps which are used to clean the middle area between the rows. The shield applicator is attached to the cultivator gang by a parallel-

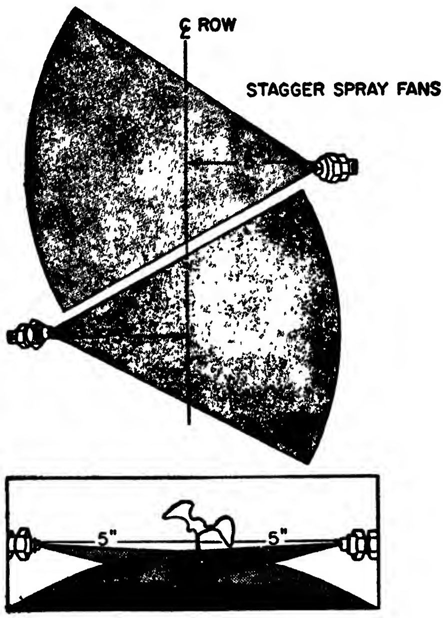

Fig. 13-30. Overhead and horizontal views of the correct method of setting nozzles for post-emergence application of chemicals for weed control.

linkage arrangement that permits the bottom edge of the shield to follow the ground surface.

Oil applications should be made at intervals of 5 to 7 days. The application should stop when the basic portion of the cotton stem begins to form a bark. The bark permits the penetration of the oil into the stem and will cause it to swell and split, thus injuring the plant. A badly split plant stem may break.

The oil is applied at the rate of 5 gallons per acre with rows spaced 40 inches apart. Except for a few changes in arrangements to support the spray nozzles, the same spray equipment that is used for pre-emergence spraying or the application of insecticides can be used for spraying of post-emergence oils. Means for adjusting the height and the angle of the spray nozzles should be provided on the shields.

For Corn. It has been found that weeds in corn can be largely controlled by the use of 2,4-D, IPC, CMU, and other chemical compounds applied as post-emergence sprays. As corn grows in height more rapidly than cotton, the spray pattern can be applied from multiple-nozzle heads attached to drops from booms that extend above and across several rows (Fig. 13-32).

Fig. 13-31. Special shoe and fender to support the spray nozzles for the post-emergence application of chemicals.

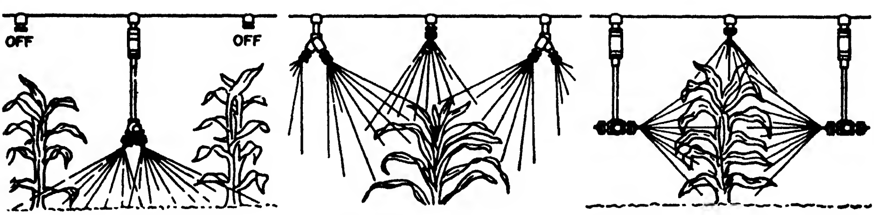

Fig. 13-32. Method of applying weed- and insect-control chemicals to corn. (*Tryco Mfg. Co., Inc.*)

A drop between the rows equipped with adjustable twin nozzles having a fan pattern of 65 to 80 degrees, set at 30 to 35 degrees from the vertical and 14 to 18 inches above the ground surface, will usually give a uniform coverage for 40-inch spaced rows (Fig. 13-33). As the corn grows taller, the boom must be raised and the drop lengthened to keep the nozzles near the ground.

For Grain and Pastures. The application of selective weed-killing chemicals to small grain crops and pastures requires a long boom set at a height which permits the nozzle pattern to give full coverage with fan-spray-pattern nozzles (Fig. 13-34). The angle of the spray fan may range from

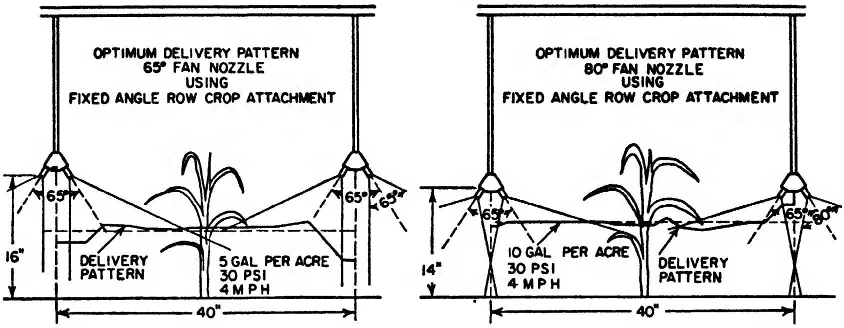

Fig. 13-33. Delivery patterns made by twin fixed-fan nozzles of 65- and 80-degree spread. The 80-degree spread gives the optimum delivery pattern for corn 14 inches in height. (*Agr. Engin.*, 29(9):383, 1948.)

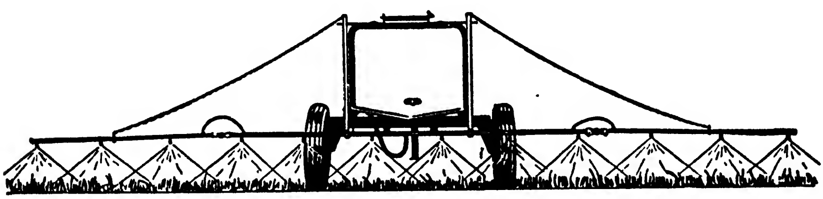

Fig. 13-34. Spraying small grain to control weeds. (*Tryco Mfg. Co., Inc.*)

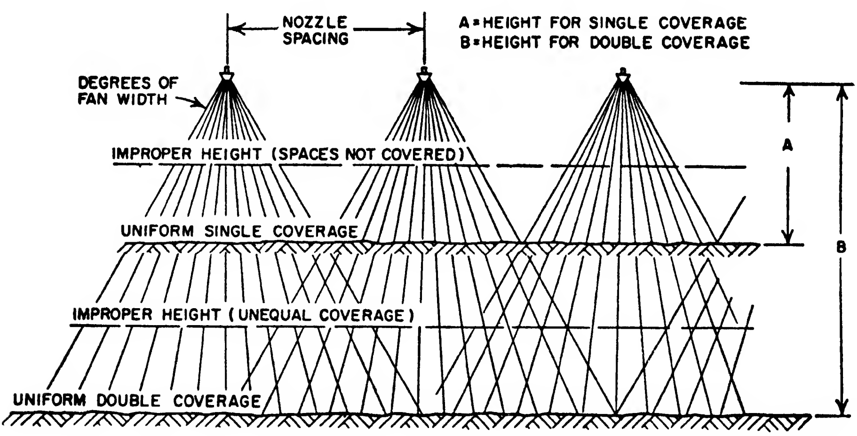

Fig. 13-35. Effect of nozzle height on the coverage obtained with the spray. (*Agr. Engin.*, 29(9):386, 1948.)

60 to 90 degrees, depending upon the conditions and height required for the boom. The nozzles can be attached directly to the boom and spaced to give full coverage according to the angle of the spray fan and the height of the boom. Figures 13-35 and 13-36 illustrate the influence of height of the boom and degrees of spray-fan width.

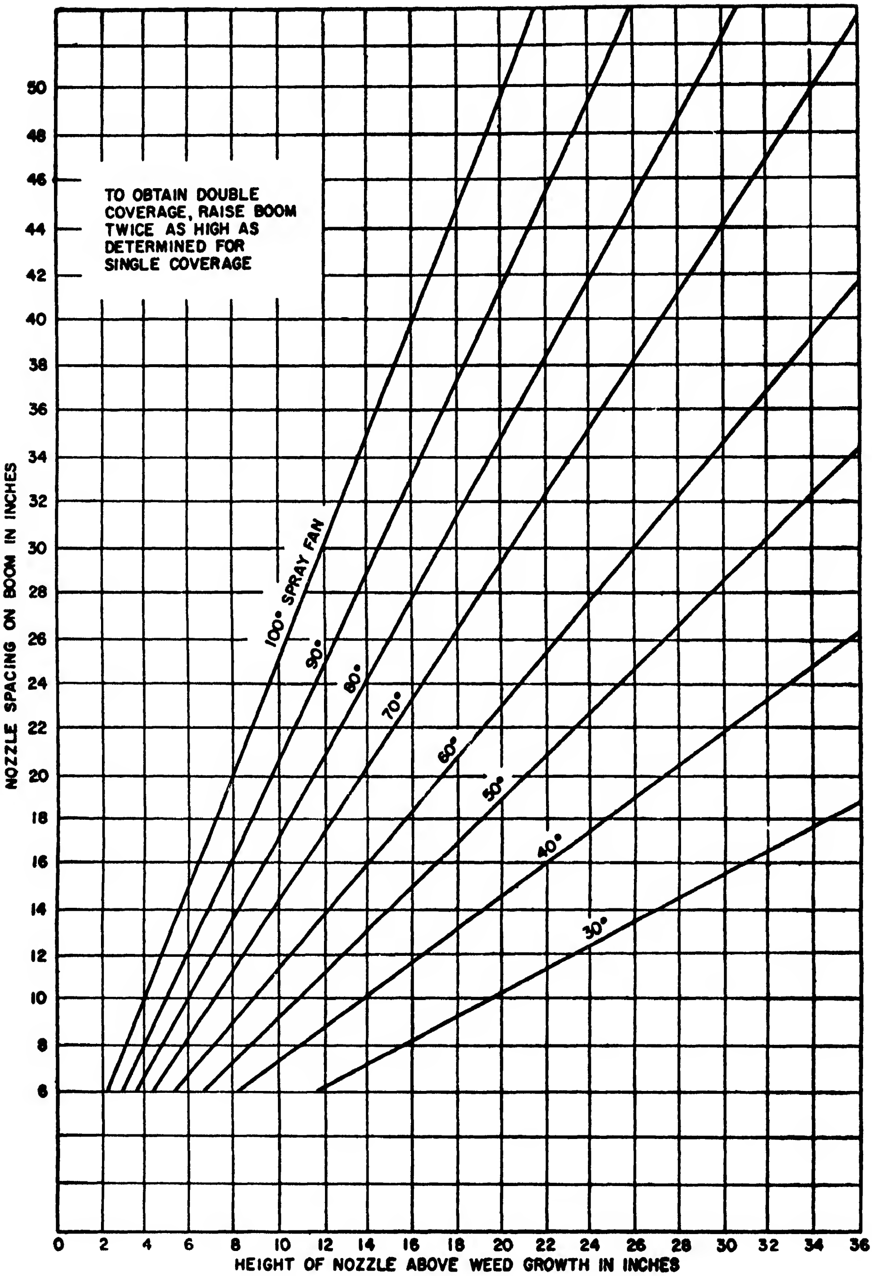

Fig. 13-36. Chart showing the height of nozzles above weeds required to give complete coverage for 6- to 48-inch nozzle spacing on boom and for various nozzle spray-fan widths. (*Agr. Engin.*, 29(9):386, 1948.)

The equipment for applying herbicides should be accurately calibrated. A method of calibrating spray rigs is given in the discussion of spray equipment in Chap. 14. The herbicides will usually cause the spray equipment to gum up, and it should be thoroughly cleaned and rinsed before and after each use.

The airplane is used extensively for the application of chemical dust and spray herbicides in the control of weeds in small grain and pastures.

Guides and Recommendations. Each state has developed guides and recommendations for the use of herbicidal chemicals. These can be obtained by writing to the State Agricultural Experiment Station. The National Cotton Council publishes a consolidated guide for all the cotton-producing states.

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QUESTIONS AND PROBLEMS

1. Discuss the importance of weed control in the culture of crops.
2. List the objectives of cultivation.
3. Explain the principal design features of central-forward-mounted tractor cultivators.
4. Explain the need for and action of delayed lifts for tractor cultivators.
5. List the various types and parts of a cultivator gang, and explain why a cultivator rear section is needed.
6. Explain how cultivator sweeps are set (*a*) with a line diagram and (*b*) with a setting frame.
7. Discuss the use of the rotary hoe as a cultivator attachment, and list six other cultivator attachments and explain their use.
8. Explain the use of flame for weed control.
9. Discuss and explain the difference between pre-emergence and post-emergence use of chemicals for weed control: (*a*) for cotton, (*b*) for corn, and (*c*) for small grains.
10. How many acres can be cultivated in a 10-hour day by a tractor and four-row cultivator traveling at the rate of 5 m.p.h. if the field efficiency is 80 per cent and rows are spaced 40 inches? Calculate the cost per acre, assuming a charge of 50 cents per hour for man labor and 75 cents per hour for tractor.

SPRAYING AND DUSTING EQUIPMENT

14

The problem of controlling insect pests and plant diseases makes it necessary for a large percentage of farmers and orchardists to include in their farm equipment machines for applying either dust or liquid insecticides and fungicides. It is estimated that insect pests and plant diseases cause an annual loss of 6.5 billion dollars. In addition to these losses, there is the cost of purchasing spraying equipment and material, maintaining the equipment, and applying the sprays and dusts.

The selection of the proper equipment to combat a certain insect pest or plant disease is a problem that needs careful consideration.

SPRAYING EQUIPMENT

History of Development. Sprayers were probably first developed and used to apply fungicides for controlling diseases of grapes in vineyards in the vicinity of Bordeaux, France. The hand sprayer to combat insects was developed between 1850 and 1860 by John Bean of California, D. B. Smith of New York, and the Brandt Brothers of Minnesota.[1]

Gasoline-engine power sprayers were developed about 1900. Tractor-mounted sprayers were not developed until several years after the introduction of the row-crop tractor in 1925. Spray booms were first attached to airplanes in the early 1940s.

[1] *U.S. Dept. Agr. Yearbook*, p. 262, 1952.

Kinds of Sprays. Spray materials will usually fall within three classifications, as (1) inorganic compounds, (2) organic compounds, and (3) the oils.

The *inorganic* compounds are of mineral origin, mainly compounds of antimony, arsenic, barium, boron, copper, fluorine, mercury, selenium, sulfur, thallium, and zinc.

The *organic* compounds are synthetic compounds. Some organic compounds have been used as sprays for many years.[1] Carbon disulfide and naphthalene have been used many decades. Other organic compounds that have been used for a quarter of a century are ethylene dichloride, ethylene dibromide, methyl bromide, and various thiocyanates. Newer groups of organic chemical spray compounds are the dinitro derivatives of phenol and cresol and the chlorinated hydrocarbons. Of this latter group DDT is the best known. Other widely used organic compounds are Toxaphene, Chlordane, Aldrin, Dieldrin, Parathion, and 2,4-D.

Petroleum oils are used alone or to supplement the action of insecticides, fungicides, and herbicides. Oils are often added to a spray as stickers, stabilizers, and conditioning agents.

Function of a Sprayer. Bronson and Anderson in the 1952 *U.S. Department of Agriculture Yearbook* define the function of a sprayer as follows:

> The main function of a sprayer is to break the liquid into droplets of effective size and distribute them uniformly over the surface or space to be protected. Another function is to regulate the amount of insecticide to avoid excessive application that might prove harmful or wasteful.
>
> A sprayer that delivers droplets large enough to wet the surface readily should be used for proper application of surface residual sprays. Extremely fine droplets tend to be diverted by air currents and be wasted.

Types of Sprayers. There is available a type of sprayer for every use, in the home, garden, orchard, and field. Garden sprayers are manually operated, but field and orchard are power operated.

Power Sprayers. The term *power sprayers* in this discussion applies to sprayers operated with either internal-combustion engines or electric motors. They may either be operated by gasoline engines of suitable size, or the sprayer may be operated by tractor power. The National Sprayer and Duster Association classifies and describes the various types of power sprayers as shown on the following pages:[2]

[1] *U.S. Dept. Agr. Yearbook*, p. 209, 1952.

[2] This copyrighted classification and description of sprayers is reproduced from the *Sprayer and Duster Manual*, 1955, of the National Sprayer and Duster Association by special permission.

Hydraulic Sprayers
- Multiple-purpose Sprayers
- Small General Use Sprayers
- High-pressure, High-volume Sprayers
- Low-pressure, Low-volume Sprayers
- Self-propelled High-clearance Sprayers

Hydro-pneumatic Sprayers
Blower Sprayers
Aerosol Generators.

HYDRAULIC SPRAYERS

Most power sprayers in use today are the hydraulic type in which the spray pressure is built up by the direct action of the pump on the liquid spray material. The pressure thus developed forces the liquid through the nozzles, which break the spray into the proper size droplets and disperse them in the spray pattern desired; also, sufficient energy is imparted to the spray droplets to carry them from the nozzle to the surface to be treated.

The essential parts of the typical hydraulic sprayer are: pump (with air chamber, if required), tank containing an agitator, framework for mounting the sprayer, combined pressure regulator and unloader or relief valve, pressure gage, strainers and screens, control valves, piping and fittings, distribution system, and power source.

Pumps. Most hydraulic sprayers are equipped with positive displacement pumps capable of developing the pressures in the range required for many spray jobs. The discharge capacity of these pumps is approximately proportional to the speed. A pressure relief or by-pass valve is required to protect these positive-acting pumps from damage when the discharge line is closed and for the convenience of the operator.

The *reciprocating pumps—plunger* and *piston* types—have been the standard of the spraying industry for many years because of their satisfactory performance in pumping almost any spray materials, including wettable powder forms of pesticides and water-base paints in a wide range of pressures. The *piston* pumps [Fig. 14-1] are commonly used in the output range of less than two to about six or eight g.p.m. and up to 400 p.s.i. or more, whereas the *plunger* type is used in the range of about seven to sixty g p.m. and pressures up to about 1000 p.s.i. Multiple units are used to achieve the higher capacities. These pumps are usually mounted on the sprayer frame although some piston types have been adapted for tractor power-take-off mounting and powering. An air chamber is supplied with *reciprocating* spray pumps to level out the pulsations of the pump and provide a constant nozzle pressure.

It should be emphasized that these pumps, which are capable of developing the higher pressures up to 800 p.s.i. or more, are also used satisfactorily at the lower pressure range of 20 to 50 p.s.i. and any pressure desired up to the indicated maximum.

Rotary pumps have been introduced into the spraying field in recent years for use in the lower pressure range. Compact and light in weight, these pumps are commonly mounted on and powered by the tractor power-take-off shaft. Oversize units are usually specified to provide sufficient by-pass liquid for hydraulic agitation in the tank. *Gear* pumps [Fig. 14-1] are classified as positive displacement and self-priming and are available in sizes up to about 20 g.p.m. Certain design features limit their use to sediment-free types of spray materials. Their service life is greatly reduced if used to pump wettable powders or any other abrasive

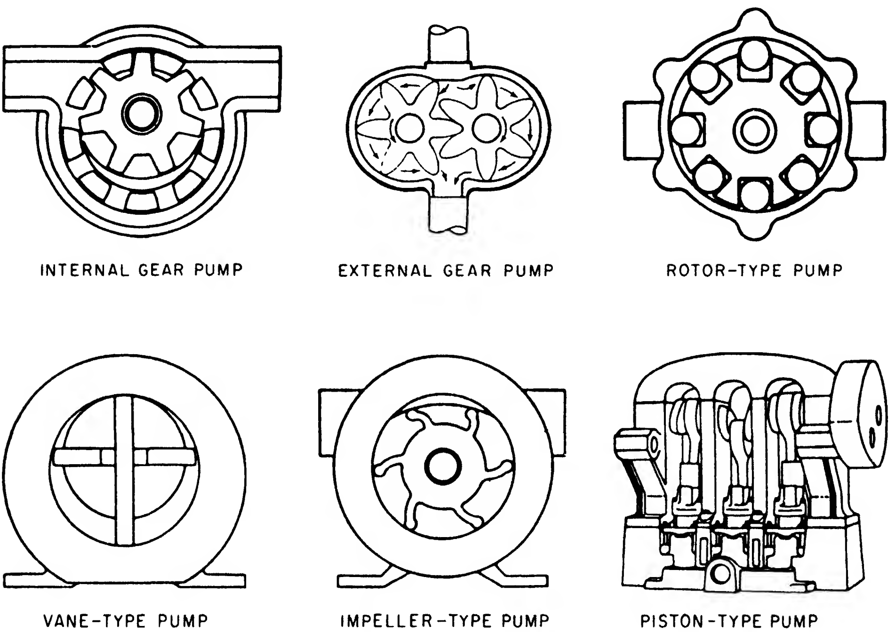

Fig. 14-1. Types of sprayer pumps.

type of spray material or if attempt is made to operate in the upper range of spraying pressures. *Vane* [Fig. 14-1] or *roller impeller pumps* have about the same operating characteristics and range of use in spraying as the *gear-type pumps*. The flexible *impeller-type pump* has performance characteristics between the positive displacement and the centrifugal pumps with a maximum operating pressure of about 50 p.s.i. Centrifugal or turbine pumps are not commonly used in sprayer design because they operate most effectively at lower pressures and higher speeds than commonly used in spraying.

Diaphragm-type pumps, suitable for spraying at pressures up to about 100 p.s.i., have also been adapted for direct mounting on the power take-off of the tractor. They are relatively unaffected by abrasive-type spray materials.

Tanks. Metal tanks are supplied on many models of power sprayers because they are easier to clean of spray residues when changing spray materials. Wood tanks, usually made of cypress, are also available, however. The size of tanks varies with the different models from about 5 gallons to 500 gallons or more capacity to suit the wide range of spraying needs. A large covered opening, fitted with a removable strainer, is provided in the top for easy filling, inspection and cleaning. A drain plug in the tank bottom permits thorough drainage when cleaning.

Agitators. Positive agitation of the spray material in the tank is essential to permit using the full range of spray materials, including wettable powders, emulsions, fungicides, cold water paints or any other sprayable

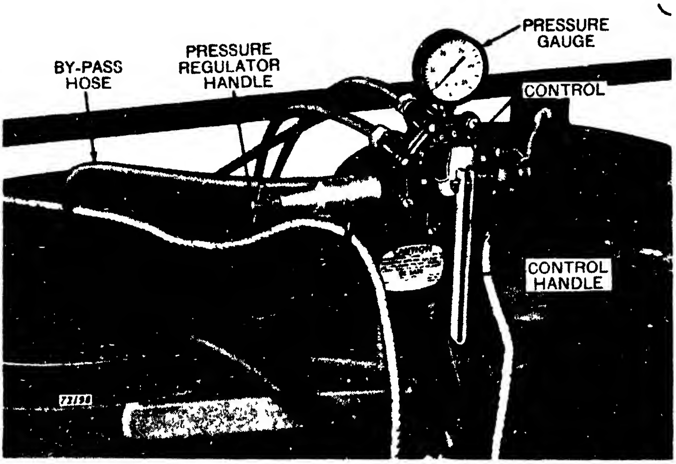

Fig. 14-2. Typical selective control valve. It has an off position, seven positions for selecting any one of any combination of three-boom sections, and an outlet for a hand gun (*Deere & Co.*)

material. A propeller or paddle-type mechanical agitator is usually provided in sprayers equipped with reciprocating-type pumps. Hydraulic agitation is used in sprayers provided with pumps mounted on the power-take-off shaft. Hydraulic agitation usually is not as thorough as mechanical agitation.

Air Chamber. With the reciprocating-type pump, an air chamber is provided on the discharge line of the pump to level out the pulsations of the pump, thereby providing a constant nozzle pressure.

Pressure Gage. A pressure gage [Fig. 14-2] properly calibrated within the pressure range of the pump, is provided on the discharge line to guide the operator in properly adjusting the pressure for each spray job.

Pressure Regulator. The pressure regulator [Fig. 14-2] serves several important functions. It is the means of adjusting the pressure as required for any spray job within the pressure range of the pump. With the positive displacement type of pump, it also serves as a safety device in auto-

matically unloading the excess pressure, directing the unused discharge flow from the pump back to the tank. When provided with an unloader, it permits the pump to operate at a greatly reduced load when the discharge line is closed.

Other Valves. One or more valves may be included in the piping system for use in connection with a tank filler [Fig. 14-3], also a ratchet-type, quick-acting, cut off valve is usually supplied to control the flow to the boom. Some boom-equipped sprayers have a special manifold-type control valve for quick flow control of any section or combination of sections of the boom [Fig. 14-3].

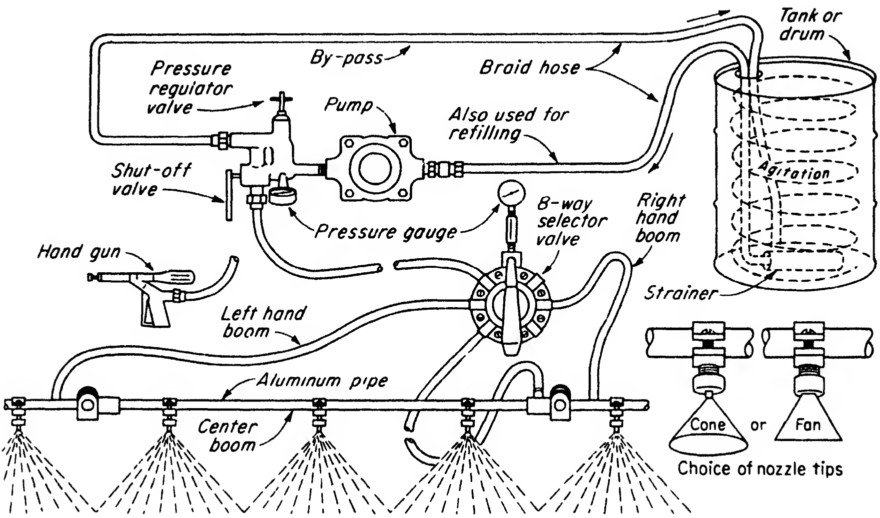

Fig. 14-3. Schematic view of typical power field sprayer operated by power take-off of the tractor. (*Allis-Chalmers Mfg. Co.*)

Strainers. A strainer is included in the suction line between the tank and the pump to remove foreign material which might affect the operation of the check valves, pump, and nozzles. These strainers, sometimes combined with a sediment bowl, are easily removed for cleaning and are replaceable.

Distribution Systems. Several types of distribution systems are used with hydraulic-type sprayers [Fig. 14-2]—a hand-held spray gun, an automatic spray head and a field boom to take care of the various types of spraying jobs. The conventional hand gun contains one or more nozzles in a suitable mounting and a fast acting control valve which serves as a cut-off and means of adjusting the spray pattern.

Automatic *spray heads* have proved effective in recent years in materially reducing the labor required in fruit tree spraying. The devices consist essentially of a number of spray nozzles arranged on a vertical boom or series of booms attached to the sprayer. Most of these devices have

an automatic oscillating mechanism to insure thorough spray penetration and coverage.

The *spray boom* or *field boom* consists essentially of a horizontal structural member on which the nozzles are properly spaced and mounted [Figs. 14-3, 14-12 and 14-13]. This member, if tubular in shape, may be used as part of the piping system to supply the spray material to the nozzles, but usually it serves only as support and protection for the liquid supply line which may be of brass or synthetic rubber mounted on or within the structural member.

The boom is adjustable vertically usually from about 18" to 72" for spraying plants of various heights and is divided into three or more sections connected by flexible joints to permit passage through farm gates and spraying uneven terrain, such as a highway shoulder and as a pro-

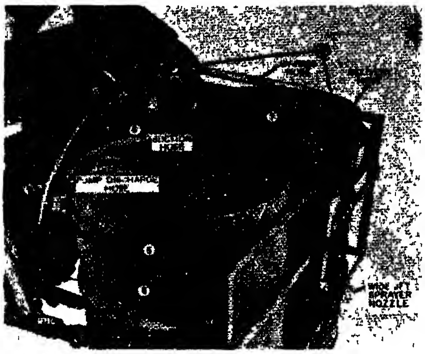

Fig. 14-4. Mounting for a boomless or wide-jet assembly for broadcast spraying. (*Deere & Co.*)

tection against damage from field obstructions. The most common length of boom for general field usage is about 21 feet with an effective spray coverage of about 23 feet or six rows spaced approximately 36" to 40" apart. The outer sections of booms 30 feet or longer are usually supported by auxiliary outrigger wheels. Counter-balanced hydraulically operated one side booms are also available for covering widths up to 40 feet or more at the side of the sprayer.

The *boomless power jet sprayer* consists of an assembly of one to five nozzles supported on a single bracket [Fig. 14-4]. The bracket may be mounted on the drawbar, front, or side of the tractor. The sprayer is adapted for the broadcast spraying of grain fields, pastures, ditches, fence rows, and orchards. The spray can be directed in any desired direction and will cover a swath from 20 to 50 feet wide, depending on the height of the nozzles and the pressure used. The pump pressure may be as high as 300 pounds.

Nozzles. The nozzle is the all-important mechanism which breaks the spray liquid into the desired size of droplets for application to the surface to be sprayed. Since no single nozzle can meet all of the various spray requirements, they are now commonly manufactured with inexpensive

replaceable nozzle tips or discs which can be selected to give the desired spray characteristics and volume for the specific job. The nozzles vary with respect to rate of discharge—gallons per minute or per acre, the angle of spray and the type of spray pattern, that is, hollow cone, solid cone or flat-fan [Fig. 14-5] Built into most nozzles is a removable strainer [Fig. 14-6] with slightly smaller openings than the nozzle orifice to prevent clogging. Nozzle drops, pendants, or drop extensions are

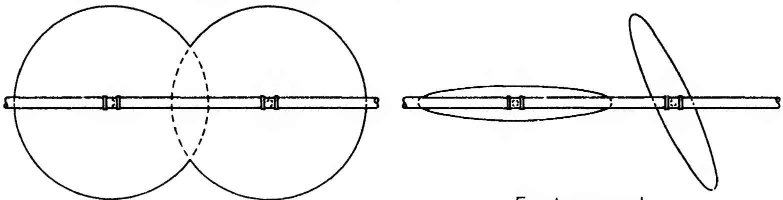

Fig. 14-5. Cone and fan nozzle-spray patterns.

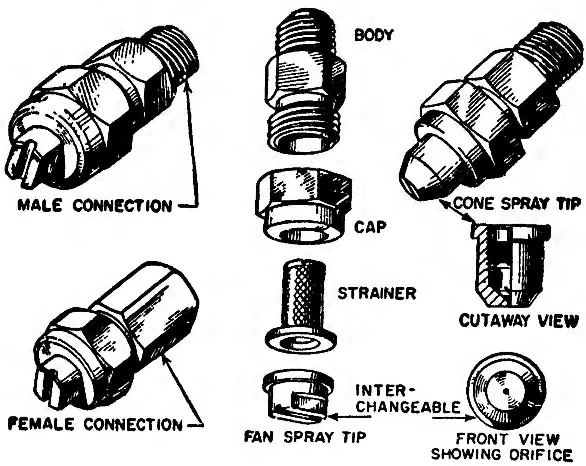

Fig 14-6. Fan- and cone-pattern spray-nozzle assemblies for applying herbicides and insecticides. (*Spraying Systems Co.*)

used for row crop work to replace the spray material more accurately [Figs. 14-7 and 14-8].

Selection of Nozzles Nozzle manufacturers' data sheets give the discharge of various nozzles at different pressures This information can be used to select the correct size for the spray job to be done. If not available, the manufacturer should be furnished the following information so that he can supply the proper nozzle:

1. Type of spray job—i.e. pasture, weed spraying, insecticide, etc.
2. Total amount of spray solution to be applied per acre for each spraying.

3. Row spacing and number of nozzles to be used per row, if application is to be on row crops.
4. Nozzle spacing if the entire area, as in pastuure work, is to be sprayed.
5. Type of spray pattern desired, such as fan or cone type.

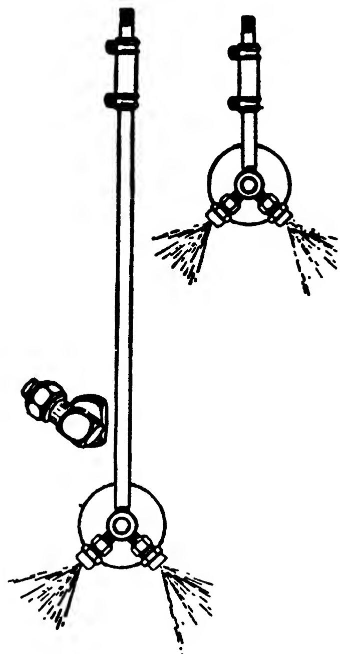

Fig. 14-7. Long and short nozzle extensions equipped with double-swivel nozzles A single-swivel nozzle is shown at left.

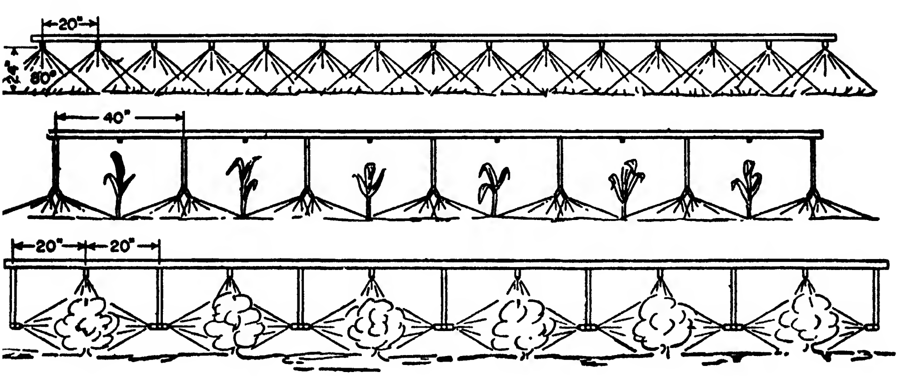

Fig. 14-8. Three methods of arranging nozzles on boom: *top*, complete overtop coverage for weeds and between narrow rows for insects; *center*, between rows for weed control; *bottom*, over and between rows for insect control. (*Wyatt Mfg. Co.*)

6. Approximate speed of travel. For tractor powered ground rigs this will usually be 3 to 5 m.p.h.
7. Approximate pressure to be used in spraying. For example, in most weed work this will be 25-40 psi, while for defoliation the pressure range will be 40-60 psi.
8. As a further aid in selecting the correct nozzle, calculations in steps 1 and 2 under the section on "Calibration" can be made with approximate average values to obtain the nozzle discharge per minute for each nozzle.

If a spray rig, complete with nozzles, is to be purchased from an equipment manufacturer or dealer, the above information will aid him in outfitting your sprayer with the proper-size nozzles.

		ARRANGEMENT OF NOZZLE TYPES					
		CONE TYPE NOZZLES				FAN TYPE NOZZLES	
	CHECK PLOT NO SPRAY	One nozzle per row	Two nozzles per row	Three nozzles per row	Nozzles spaced 20" apart on boom	Nozzles spaced 20" apart on boom	One nozzle per row
Year	Yield per acre — pounds seed cotton						
1955	825	1,275	1,160	1,145	1,315	1,280	1,365
1956	315	402	357	500	434	472	419
Av 52-56	759	1,244 (5yr)	1,226 (5yr)	1,219 (5yr)	956 (3yr)	907 (3yr)	921 (3yr)
		Cone pattern				Fan pattern	

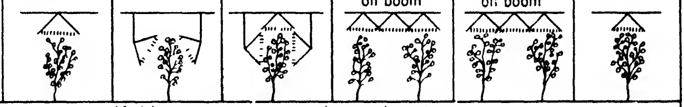

Fig. 14-9. Effect of nozzle type and arrangement on the control of cotton insects as measured by yield. (*Texas Agricultural Experiment Station.*)

Effect of Nozzle Type and Arrangement. The author[4] and co-workers[5] began a study in 1952 to determine the effect of nozzle type and arrangement on the control of cotton insects.

The results covering a 5-year period show that a single hollow cone nozzle directly over the row gave better insect control and resulted in higher yields of seed cotton than two and three nozzles arranged about the row of plants (Fig. 14-9). The fan- and boomless-type spray nozzles

[4] H. P. Smith and R. L. Hanna, Effects of Type and Arrangement of Spray Nozzle on the Control of Bollworm and Boll Weevil, *Tex. Agr. Expt. Sta. Prog. Rpt.* 1752, 1955.

H. P. Smith, C. M. Hohn, and R. L. Hanna, Effects of Spray Nozzle Types and Arrangements on Cotton Insect Control, *Tex. Agr. Expt. Sta. Prog. Rpt.* 1906, 1956.

[5] L. H. Wilkes, P. L. Adkisson, and R. J. Cockran, Effect of Spray Nozzle Types on Cotton Insect Control, *Tex. Agr. Expt. Sta. Prog. Rpt.* 2078, 1959.

did not give as good results as the hollow nozzle (Fig. 14-10). Figure 14-11 shows the relative size of spray droplets made by a boomjet nozzle across six rows spaced 40 inches apart. The highest yields were produced on the rows nearest the nozzle and where a more complete coverage was obtained with the smaller droplets.

Types of Sprayer Mounting. Most sizes of hydraulic sprayers are available mounted either on skids or on wheels. The skid models, of course, are less expensive and preferred for many stationary spraying jobs. They can be transported in truck, wagon, trailer or jeep or the smaller models with 50 gallon or smaller tanks may be mounted on a platform on the rear of a farm tractor. The wheel mounted models usu-

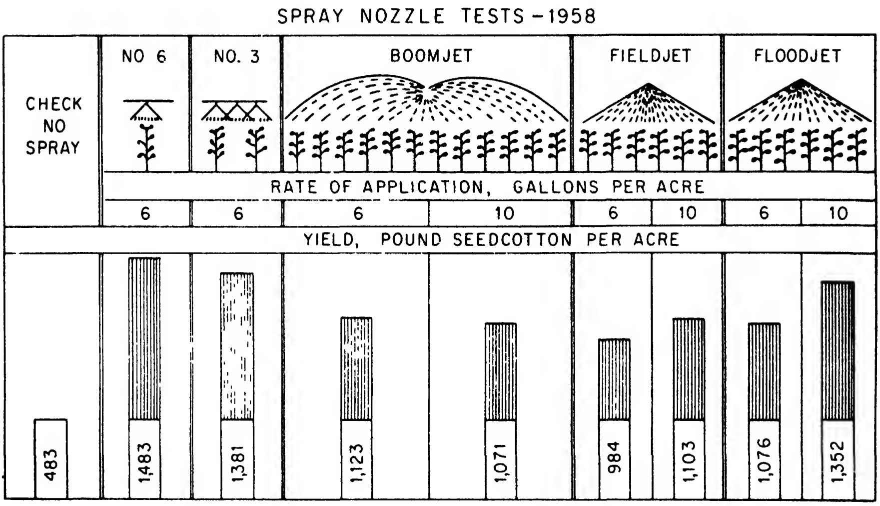

Fig. 14-10. Effect of nozzle types and rate of application on the control of cotton insects as measured by yield. (*Texas Agricultural Experiment Station.*)

ally have two wheels, although some are mounted on four. Some special use sprayers are designed for direct mounting on the tractor frame.

Power Source. Power is supplied to the skid models by an engine or electric motor which is an integral part of the unit. Wheel mounted models may be powered by a self-contained engine or by the power-take-off shaft of the towing tractor or truck. The size of the engine furnished varies with the pump capacity and pressure range. Most pumps of tractor-mounted sprayers are powered by direct connection to the power-take-off shaft or by the belt pulley. Others are engine powered.

Tank Filler. This is a useful device which utilizes the sprayer pump through an injector in filling the tank rapidly from any convenient source of clean water, such as a stock watering tank, cistern, pond or stream. A typical unit consists of an injector, a 15′ or 20′ length of suction hose

equipped with a strainer and foot valve and connection for attachment to the piping system of the sprayer. For best operation the source of water should be within 10′ to 12′ vertical distance from the sprayer pump.

Multiple-purpose Farm Sprayers. This type of sprayer has been developed to provide in one machine the versatility required to meet the many spraying needs on diversified farms. It has the necessary pressure range to be used for weed spraying at 30 to 50 pounds or for spraying fruit trees or livestock at pressures in the range of 250 to 400 pounds or more

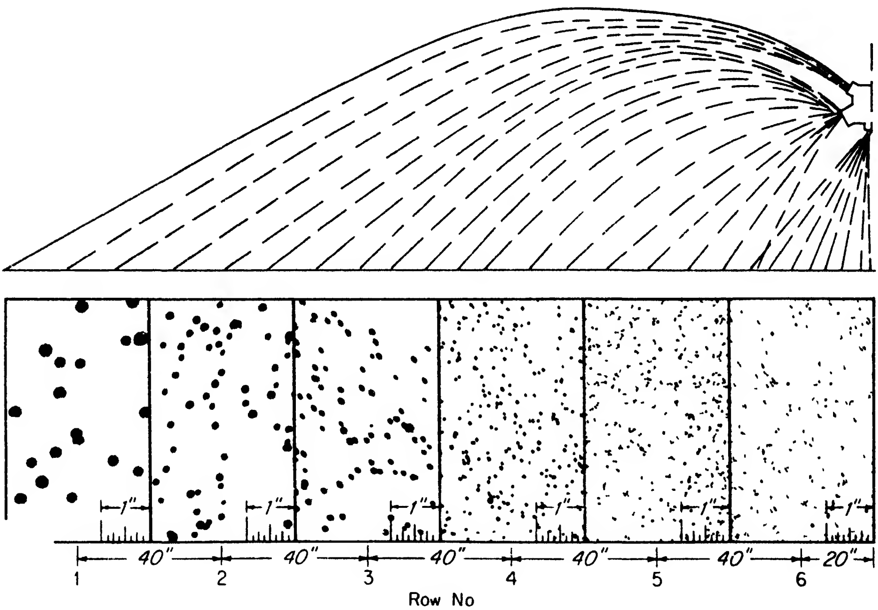

Fig. 14-11. Showing the relative size of spray droplets made by a wide-jet spray nozzle across six rows spaced 40 inches apart. (*Texas Agricultural Experiment Station.*)

or any pressure in between. Because of the type of pump and agitation provided, the user has a free choice of spray materials since wettable powders, cold water paints and other spray materials which are abrasive or difficult to keep in suspension can be used satisfactorily in this type of sprayer.

Reciprocating piston or plunger-type pumps are used which deliver in the range of 3 to 8 g.p.m. at pressures up to 250, 400 or even 800 pounds. Mechanical agitation is provided in the tank which is available in sizes from 50 to about 200 gallons. Identical sizes are usually available in both skid and wheel mounted types.

The skid models are powered by an auxiliary engine. The wheel mounted models are powered either by the power-take-off shaft or by an auxiliary engine. These sprayers are usually furnished with a hand gun

and proper length of hose. Field booms 20 to 30 feet in length are generally available as optional equipment.

Small General Use Sprayers. Small general use sprayers are available for those spraying jobs which are just too large or too tedious for coverage with hand equipment. They are popular for use on golf greens, estates, acreages, large gardens or greenhouses. Included in this class are the power wheelbarrow sprayer, the estate or small wheel mounted sprayer and the small skid mounted units.

Power wheelbarrow sprayers have reciprocating-type pumps which deliver 1½ to 3 g.p.m. and develop pressures up to 250 pounds. Power is furnished by an air cooled engine of ⅔ to 1½ h.p. For greenhouses or other interior stationary jobs, the sprayer can be operated by a ½ h.p. heavy duty electric motor. The tank capacities of the different makes vary from 12½ to 18 gallons. Standard equipment includes mechanical or jet agitator, pressure gage, pressure regulator and relief valve and an adjustable hand gun and hose. Some makes can be provided with a spray boom.

High-pressure, High-volume Sprayers. These sprayers used by the commercial growers of fruit and truck crops are the product of many years of successful development by the manufacturers in cooperation with the growers. The machines combine the high pressure and volume delivery desired to get complete spray coverage of high growing fruit and shade trees in full foliage, as well as the dense growth of vine and other truck crops.

The essential parts of these sprayers are basically of the same design as those described for the multiple-purpose farm sprayers with a few important exceptions as follows:

Plunger-type, multiple-cylinder reciprocating pumps are used almost exclusively with these larger sprayers, delivering from about 8 to 60 g.p.m. at maximum pressures in the range of 400 to 1000 p.s.i. Tank sizes are also correspondingly larger. Sprayers having pumps discharging up to 50 or 60 g.p.m. can be furnished with tanks up to 600 gallons capacity.

Field booms designed for use with these sprayers may be of an adjustable type or of special design for use primarily on one specific crop. Nozzles commonly used are of the large volume type producing a cone shaped pattern. For many crops the nozzles are suspended on pendants or nozzle drops to permit complete underleaf coverage of foliage. The hydraulically operated one side boom is often used with these sprayers for such crops as potatoes and tomatoes.

For fruit tree work the spray may be applied by a hand gun or an automatic spray head. The modern guns have been improved in design for quick shutoff, easy handling and for adjustment of the spray pattern. Safety towers mounted on the top or rear of the sprayers are available for more accurate spray placement and the protection and convenience of the operators. Automatic spray heads can be supplied with new equipment or furnished to convert older sprayers to one-man operation.

Low-pressure, Low-volume Sprayers. These sprayers have been designed primarily to meet the specific requirements for low-pressure, low-volume field spraying. Because of their relatively low cost, they have proved popular for use in controlling weeds and insects in field crops and for other spray jobs for which pressures under 100 pounds are satisfactory. Their use also is usually limited to the sediment-free type of spray materials due to the type of pump and agitation provided.

Two different models of these sprayers are available—*tractor mounted* and *wheel mounted.* The *tractor-mounted* unit consists of a kit of component parts which are mounted by the user on the tractor [Fig. 14-12]. Included in the kit are a pump, strainer, control valves, pressure gage, pressure regulator and relief valve, spray boom and brackets for

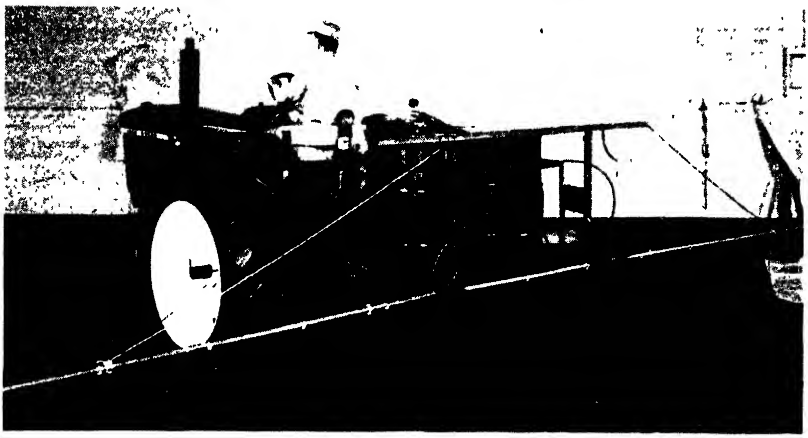

Fig. 14-12. Tractor-mounted field sprayer. (*Deere & Co.*)

mounting the boom and one or more metal drums. A rotary-type pump is usually supplied for direct mounting on the tractor power-take-off shaft. Hydraulic agitation is provided by the by-pass from the pump.

The *wheel-mounted* or *trailer-type* sprayers [Fig. 14-13] in this class have the same performance characteristics and field use as the tractor-mounted units discussed above. They are more quickly readied for use, however, since the tank and boom are permanently mounted on the trailer. The tractor-powered units require mounting the pump on the tractor and connecting it to the power source for each use. Some models, however, have a self-contained engine. A conventional sprayer tank of from 50 to 250 gallons capacity is supplied with some units. Others are provided with one or more 50 gallon metal drums mounted on the trailer frame. These trailer tank units also can be used to convert a tractor-mounted, tractor-powered sprayer to the more convenient trailer-type machine.

Self-propelled High-clearance Sprayers. This sprayer has been developed as a special purpose machine to spray those field and row crops

which are too high for conventional power sprayers and tractors. With the sprayer removed, the carrier unit or chassis is useful for detasseling corn and for transporting vegetables and crates in the field.

The carrier to which the sprayer is attached may consist basically of a row-crop tractor [Fig. 14-14] which has been modified to clear plants

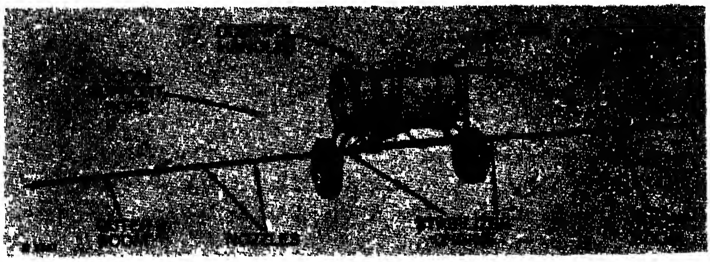

Fig. 14-13. Trailer-type field sprayer. Note that the nozzles are attached directly to the boom. (*Deere & Co.*)

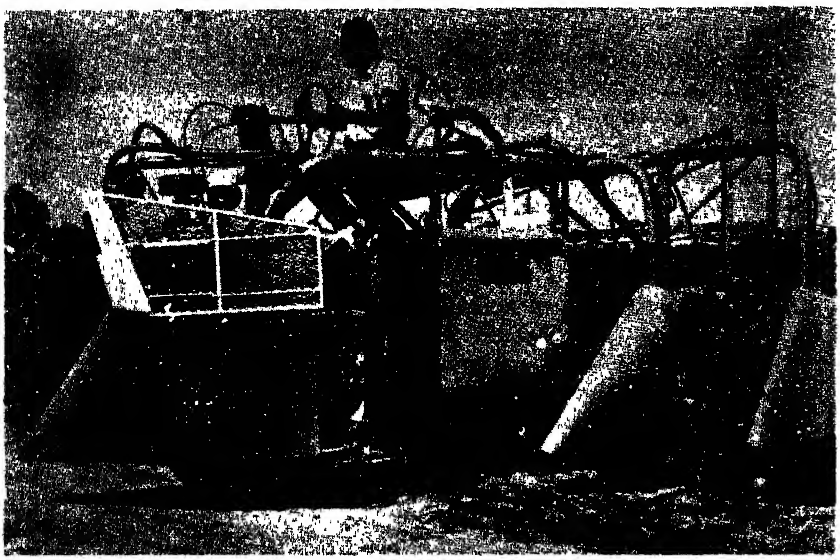

Fig. 14-14. Self-propelled high-clearance sprayer equipped with fenders, which are essential when spraying cotton, corn, and other tall crops in mid and late season. (*Hahn, Inc.*)

5 to 8 feet high or it may be a specially designed chassis which is usually powered by an air cooled engine. The heavy duty units designed around a farm tractor are usually supplied with a multiple-purpose, skid-type sprayer which is attached to the frame of the carrier. These sprayers may have either three or four wheels and the power is usually applied to

the rear wheels. The units powered by an air cooled engine usually have three wheels and the power is commonly applied to the front wheel. These machines usually are equipped with a low-pressure, low-volume sprayer, and a second engine is often provided to power the sprayer. The spray boom is usually mounted on the rear of the machine. The height of the boom can be varied to permit spraying either high or low growing crops.

HYDRO–PNEUMATIC SPRAYERS

Sprayers of this type have about the same range of use as the low-pressure, low-volume sprayers previously described. The spray liquid is carried in a pressure tank and the spraying pressure is developed by means of an engine-powered air compressor. The spray material therefore does not pass through a pump or contact any other moving parts.

These sprayers are available mounted on skids or wheels. Because of the cost and weight of pressure tanks, the tank size is usually limited to less than 300 gallons and maximum working pressure to 75 to 100 pounds. The compressors are usually rated in cubic feet per minute volume at atmospheric pressure. One cubic foot per minute at the desired pressure, therefore, will equal about 7½ gallons per minute. Agitation is provided either by means of a mechanical agitator or by an air tube discharging air below the surface of the liquid in the tank. These units are almost always powered by a self-contained engine.

BLOWER SPRAYERS

These relatively new sprayers [Figs. 14-15 and 14-16], also known as concentrate or mist sprayers, have been developed to apply pesticides in concentrated form. Substantial saving in labor costs is thereby effected since the quantity of water required as a diluent may be reduced from 20 to 80 per cent or more as compared with conventional dilute methods of spraying. Further savings are also reported in the quantity of chemicals used, since runoff from foliage may be reduced when the equipment is properly operated.

These sprayers are used for treating large acreages of fruit trees, large shade trees, vegetables and certain other crops. Large fruit trees may require thinning and pruning to permit proper penetration of the small airborne droplets to the inner and top-most branches. The swath or strip covered will vary with wind direction and velocity.

These machines are basically similar to power dusters in that a blast of air is employed to carry the chemical from the machine to the foliage to be treated except, of course, that the chemical is in liquid, rather than dry, form. The typical concentrate sprayer of the blower type utilizes a low-pressure, low-volume pump which forces the spray material under low pressure to the fan where it is discharged into the airstream in small

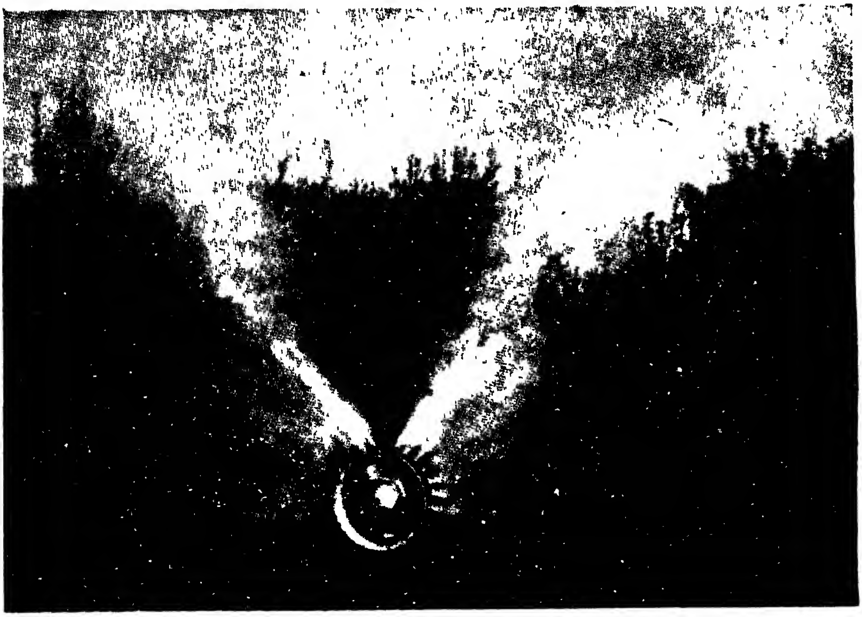

Fig. 14-15. Blower-type sprayer in operation. (*John Bean Division, Food Machinery and Chemical Corp.*)

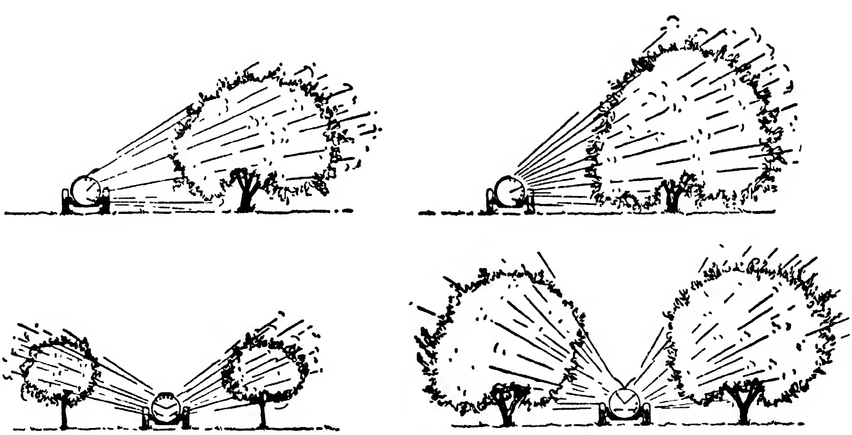

Fig 14-16. Four spray patterns that can be delivered by blower sprayers. (*John Bean Division, Food Machinery and Chemical Corp.*)

spray droplets by a group of nozzles or a shear plate. The air stream assists in breaking up the liquid into small particles, acts as a diluent to prevent the drops from coalescing and serves as the vehicle to carry these fine droplets to the surface to be treated.

Several types of pumps in the range of 1 to 8 g.p.m. and 50 to 400 pounds pressure are used with these machines. Both axial flow and centrifugal-type fans or blowers are used. The low volume units have fans delivering under 5000 c.f.m. and at velocities over 150 m.p.h. They commonly have an outlet diameter of 1" to 3" and are powered by a 1 to 2 h.p. engine. The fans provided for these units deliver an air volume in the range of 5,000 to 25,000 c.f.m. and velocities in the range of 100 to 150 m.p.h. The high volume units commonly deliver over 25,000 c.f.m. at velocities under 100 m.p.h. These large units require engines as large as 65 h.p. depending upon the type and size of blower.

AEROSOL GENERATORS—FOG MACHINES

These machines disperse the spray material in the form of extremely fine droplets (1-50 microns[6] in diameter) which remain airborne for a considerable period of time. The insect kill with this equipment is dependent upon the airborne insecticide contacting the insects since there is usually little or no residual action. This equipment is employed for the temporary control of adult mosquitoes, flies and other similar insects in buildings and in restricted areas such as ballparks, picnic grounds, resort areas or even large communities

CONTROLLING THE SPRAY APPLICATION

The gallons per acre applied on a field will depend upon (1) the forward speed of the sprayer and (2) the number of nozzles and their rate of discharge.

The importance of forward speed is readily apparent. If the forward speed is suddenly changed from 5 to 10 m.p.h. or doubled, then the nozzles will have only half the time to deliver their spray in traveling a given distance, and the gallons applied in that distance will, therefore, be cut in half. Constant speed is especially important in applying sprays at high concentrations, that is, low gallonage rates. At a given throttle setting, tractor speeds will be fairly constant on level terrain. On the other hand there may be considerable variation in speed going up and down hills. For extensive spraying operations a tractor speedometer is recommended as insurance against the high cost and possible damage of over-dosing and the ineffectiveness of under-dosing. Changing from one constant rate of travel to another is a means of changing the rate of spray application on a field within the range of practical operational speeds.

[6] A micron is a thousandth of a millimeter; a section of a diameter between one-hundredth and one-millionth of a millimeter.

Thus patches of heavy weed growth can be given a heavier rate of application than the remainder of the field merely by reducing the forward speed over such areas.

Effective spraying cannot be done when the wind velocity is above 10 m.p.h. A simple wind gage should be used to determine the wind velocity.

Assuming a fixed number of nozzles on a sprayer, the rate of discharge can be changed by increasing or decreasing the sprayer pressure within certain limits or by replacing the nozzles, nozzle tips or discs with similar units of a higher or lower capacity.

There are certain limitations to increasing the rate of delivery of nozzles by increasing the pressure. Increasing the pressure does not proportionately increase the discharge rate. For most nozzles the pressure must be increased about four times to double the delivery output. Increasing the pressure also tends to decrease the droplet size of the spray delivered and thus increase spray drift. The spray pattern may also be affected. Generally speaking the pressure should not be varied more than 25% above or below the optimum pressure for the nozzle. Instead, changing to a nozzle tip or disc of the desired rated capacity is the preferred method of changing to a substantially different rate of spray application.

In some spraying operations it is desirable to change the rate of application by changing the number of nozzles on the boom. Thus in the case of some row crops the number of nozzles covering each row is increased from one to three or more as the size of the plants increase and present a larger surface area of foliage to be covered.

The practical relationship of these various factors of forward speed, pump capacity, nozzle size and length of boom is demonstrated in the several computations which follow for determining length of boom, size of pump and size of nozzle required for specific jobs:

CALIBRATION OF SPRAYERS

Before starting to spray a field the sprayer should be calibrated or checked to determine if it is delivering the spray material at the desired rate. As previously stated, the rate of application will be determined by the rate of discharge of the nozzles and by the rate of forward speed. If the sprayer has the required size nozzles and is functioning properly at the required pressure, then the principal purpose of the test is to establish the proper rate of forward speed. A tractor speedometer, although not essential, proves very useful in maintaining a uniform rate of travel.

The essential steps in calibrating the equipment are as follows:

1. Set two stakes 40 rods apart (660 feet).
2. Fill sprayer tank with water. Operate the sprayer to be sure the entire supply line up to the shut-off valve is full before finally filling the tank and recording the water line on a measuring stick.

3. *Drive sprayer round trip between stakes* (80 *rods total*) *at the desired speed and with the sprayer in full operation.* The sprayer should be moving at normal speed with pressure up and the valve should be opened as it passes the first stake in each direction. Mark the throttle setting.
4. *Carefully measure the amount of water required to refill the tank after the test.* Before refilling to the same mark on the measuring stick, be sure that the sprayer is in the same location as for the first filling or is resting level in both instances to avoid possible error.
5. *Multiply gallons used to refill tank by* 33 *and divide by width sprayed in feet. This gives gallons per acre applied.*

Example: Assume it is desired to apply a spray material at the rate of 10 gallons per acre traveling at a forward speed of 5 m.p.h. and with a boom 20 ft. long. If 5 gallons of water were required to refill the tank after the calibration, then the actual rate of application is determined as follows:

$$\text{g.p.a.} = \frac{5 \times 33}{20} = 8.2 \text{ gallons per acre}.$$

Since this rate of application is lower than desired, the forward speed must have been greater than 5 m.p.h. Therefore, the test should be repeated using a throttle setting which will give a slightly slower rate of travel.

Sprayers should be calibrated at least once each season at the start, and as frequently thereafter as a different rate of application is used or as the need may be indicated from checking approximate quantities of spray materials used on fields of known size.

Wettable powders and other suspensions should be applied at relatively low pressures to avoid excessive erosion of nozzle discs or tips which will result in increase in discharge rate.

Replacing the nozzle discs or tips as frequently as excessive erosion is indicated is cheaper than overdosing.

FORMULAE FOR SPRAYERS

$$\text{(1) Length of boom in feet} = \frac{\text{area to be treated}}{\text{time available} \times \text{tractor speed}}$$

$$= \frac{\text{square feet}}{\text{working hours} \times \text{feet per hour}}$$

$$= \frac{43560 \times \text{acres}}{\text{working hours} \times 5280 \times \text{miles per hour}}$$

Example: What length of boom is required on a sprayer operating at 5 miles per hour to permit spraying an 80 acre field in 8 working hours

(70% of time spent in actual spraying, 30% in filling tank, turning, etc.)?

$$\text{Length of boom} = \frac{43560 \times 80}{.7 \times 8 \times 5280 \times 5}$$

$$= 23.6 \text{ feet (use closest standard size of boom)}$$

(2) $$\text{Pump output in g.p.m.} = \left(\begin{array}{c}\text{sq. ft. per min.}\\ \text{to be covered}\end{array}\right) \times \left(\begin{array}{c}\text{gal. per sq. ft.}\\ \text{to be applied}\end{array}\right)$$

$$= \text{ft. per min.} \times \text{boom length} \times \text{gal. per sq. ft.}$$

$$= \frac{5280 \times \text{m.p.h.} \times \text{boom length} \times \text{g.p.a.}}{60 \times 43560}$$

Example: a. What minimum size pump is required to apply a spray at 10 gallons per acre with a sprayer operated at 5 m.p.h. and equipped with a boom 25 ft. long?

$$\text{Pump output or capacity} = \frac{5280 \times 5 \times 25 \times 10}{60 \times 43560}$$

$$= 2.5 \text{ gallons per min.}$$

b. What is the maximum rate of application in gallons per acre of a sprayer equipped with a 7 g.p.m. pump and a boom 20 ft. long when operated at 5 m.p.h.?

From the above relationship we have:

$$\text{Gallons per acre} = \frac{\text{pump output in g.p.m.}}{\text{acres covered per minute}}$$

$$= \frac{7 \times 60 \times 43560}{5280 \times 5 \times 20} = 34.6 \text{ g.p.a.}$$

To apply the spray material at a higher rate with this sprayer either (1) reduce the forward speed or (2) use a shorter boom or only a portion of this boom, plugging unused nozzles.

(3) $$\text{Output per nozzle in g.p.m.} = \frac{\text{pump output in g.p.m.}}{\text{number of nozzles}}$$

$$= \text{pump output} \times \frac{\text{nozzle spacing}}{\text{length of boom}}$$

$$= \frac{\text{gal. per acre}}{43560} \times \frac{\text{m.p.h.} \times 5280}{60} \times \frac{\text{nozzle spacing}}{12}$$

Example: What size nozzles should be used for an application of 20 gallons per acre with the sprayer traveling 5 m.p.h. and the nozzles spaced 20 inches apart on the boom?

$$\text{g.p.m. per nozzle} = \frac{20 \times 5 \times 5280 \times 20}{43560 \times 60 \times 12}$$

$$= 0.337 \text{ g.p.m.}$$

TABLE 14-1. SPRAYING TIME PER ACRE*

Speed, m.p.h.	Width of boom						
	10′	15′	20′	25′	30′	40′	50′
	Minutes required to spray 1 acre						
2	24.8	16.5	12.4	10.0	8.3	6.2	5.0
3	16.5	11.0	8.3	7.0	5.5	4.1	3.3
4	12.4	8.2	6.2	5.0	4.1	3.1	2.5
5	9.9	7.0	5.0	4.0	3.3	2.5	2.0
6	8.3	5.5	4.2	3.3	2.8	2.1	1.5
7	7.1	4.7	3.5	2.8	2 4	1.8	1.4
8	6.2	4.1	3.1	2.5	2 1	1.6	1.2
9	5.5	3.7	2.8	2.2	1.8	1.4	1.1
10	5.0	3.3	2.5	2.0	1 7	1.2	1.0

* No allowance made for turning or for filling or servicing sprayer.

TABLE 14-2. TRAVEL SPEED

M.p.h.	Ft. per min.	Time required to travel*									
		100 ft.		500 ft.		660 ft. (40 rds.)		1,320 ft. (80 rds.) (¼ mi.)		2,640 ft. (160 rds.) (½ mi.)	
		min.	sec.	min.	sec.	min.	sec.	min.	sec.	min.	sec.
1	88	1	8	5	39	7	30	15	0	30	0
2	176	0	34	2	50	3	45	7	30	15	0
3	264	0	23	1	55	2	30	5	0	10	0
4	352	0	17	1	25	1	53	3	45	7	30
5	440	0	14	1	8	1	30	3	0	6	0
10	880	0	7	0	34	0	45	1	30	3	0

* To closest second.

AIRPLANE SPRAYER

The use of the airplane to apply and distribute spray material has become one of the most popular and economical methods of applying insecticides and fungicides to agricultural crops.

War-surplus aircraft of the Boeing Stearman biplane type (Fig. 14-17) is the most popular type of aircraft for agricultural spraying. The Personal Aircraft Research Center of the Texas Agricultural and Mechanical College and various cooperating agencies have, under the direction of Professor Fred E. Weick, designed and built an airplane especially suited for agricultural work. There are now a number of commercial aircraft

using many of the principles of this development. Figure 14-18 shows a commercial plane. This plane has been used to study the influence of nozzle spacings on the spray patterns. The arrangement and location of the nozzles on the boom under the airplane were studied. It was found that the center of deposit for each nozzle did not directly follow the arrangement of the nozzles. As shown in Fig. 14-19 the center of deposit for each nozzle 16 feet from the center of the aircraft (dotted line) was

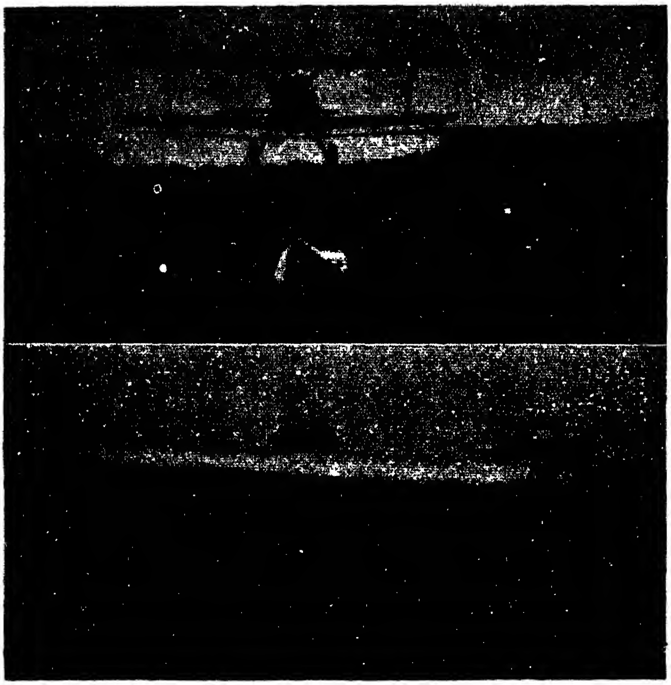

Fig. 14-17. Front and side views of airplane applying liquid spray to cotton. (*Texas Agricultural Experiment Station.*)

farther out than for a nozzle located 17 feet from the center of the aircraft. It is noted that there was no cross wind in these tests.

Cross winds influence the spray pattern and uniform distribution of spray materials applied by aircraft, as shown in Fig. 14-20. The top section of the illustration shows the weighing units used to collect the spray material across the spray pattern made by the aircraft. The center and bottom sections of the illustration show the volume of material collected by each of the weighing units. The height of the column represents the load on the scale as deposited in a single swath. It is noted that the cross wind of 2 m.p.h. caused a considerable drift to the left.

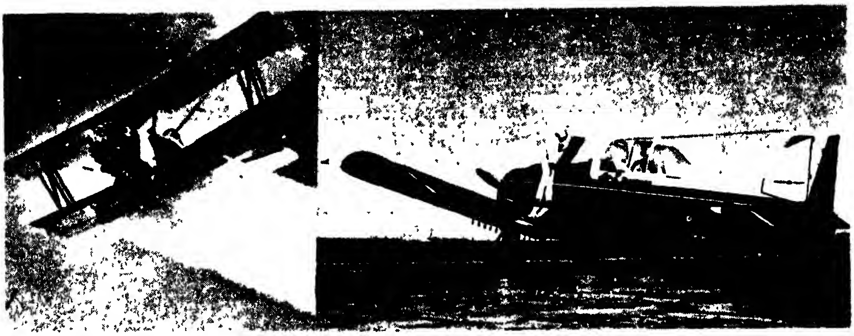

Fig. 14-18. Two commercial agricultural airplanes. The plane on the left is equipped with a special swather. (*Transland Aircraft Division, Hi-Shear Corp.*)

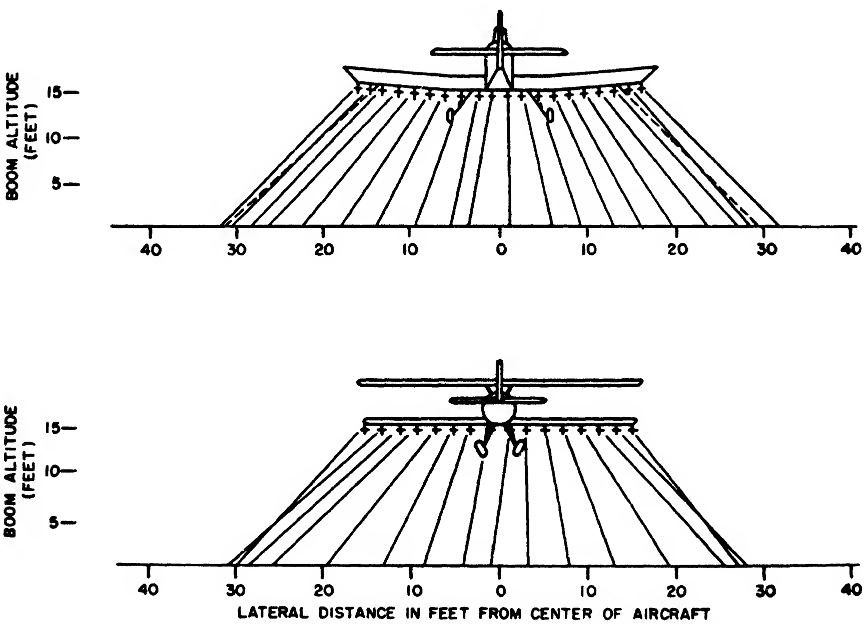

Fig. 14-19. Some nozzle locations on the Agricultural (*top*) and Boeing Stearman (*bottom*) aircraft with their respective centers of deposit at ground level (zero cross wind). (*Texas Engineering Experiment Station, Aeronautical Laboratory.*)

Effect of Droplet Size on Coverage and Drift. Table 14-3 shows the effect of droplet size on the coverage and drift for a dispersal rate of 4 gallons per acre. The table shows that rain-sized droplets in a 10-m.p.h. wind will drift from 14 feet for large-sized raindrops to 62 feet for small-sized raindrops. Fine droplets from aerosol sprays may drift as far as 280 miles.

TABLE 14-3. EFFECT OF DROPLET SIZE ON COVERAGE AND DRIFT FOR DISPERSAL RATE OF 4 GALLONS PER ACRE

Assuming uniform droplet size and spacing, and no evaporation loss

Diameter of droplets, microns	No. per sq. in.	Distance between droplets, in.	Time to fall 10 ft.	Distance carried in 10 m.p.h. uniform drift	Notes
1,650	1	1.0	1.0 sec.	14 ft.	Heavy rain. Diam. of pin head. Largest recorded at A. & M.
1,000	4.6	0.47	1 1 sec.	16 ft.	Moderate rain
500	37	0.16	1.6 sec.	23 ft.	Light rain
200	570	0.043	4 2 sec.	62 ft.	Drizzle
100	4,600	0 015	11 sec.	170 ft.	Mist
50	36,800	0 005	40 sec.	592 ft.	Smallest size recorded at A. & M.
10	4 6 million	0 0005	17 min.	2.8 mi.	Aerosol
1	4 6 billion	0 000015	28 hr.	280 mi.	Aerosol

SOURCE: Personal Aircraft Research Center, Texas Agricultural Experiment Station, College Station, Texas.

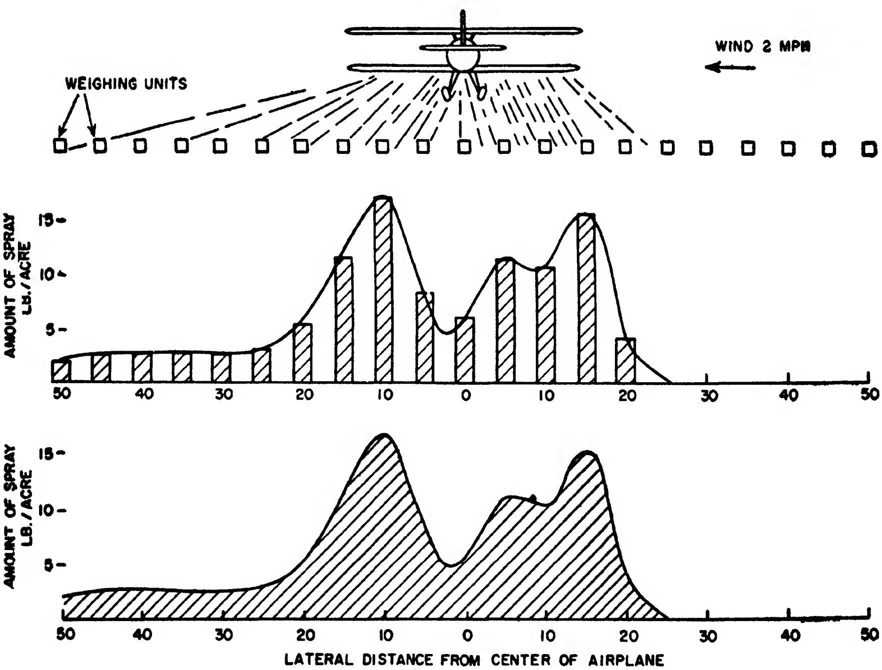

Fig. 14-20. Typical spray pattern for a single swath for a Boeing Stearman plane. (*Texas Engineering Experiment Station, Aeronautical Laboratory.*)

Sprayer Nozzles for Aircraft. As shown in Fig. 14-21, there are two types of nozzles available for spraying liquids with aircraft. Each type of nozzle has a check valve to stop the flow of the liquid when the pressure is cut off. It is claimed that, when the spray droplets are discharged from the side of the nozzle into the air stream, the shearing action of the air at high velocity as it passes the nozzle tip will further reduce the size of the droplet.

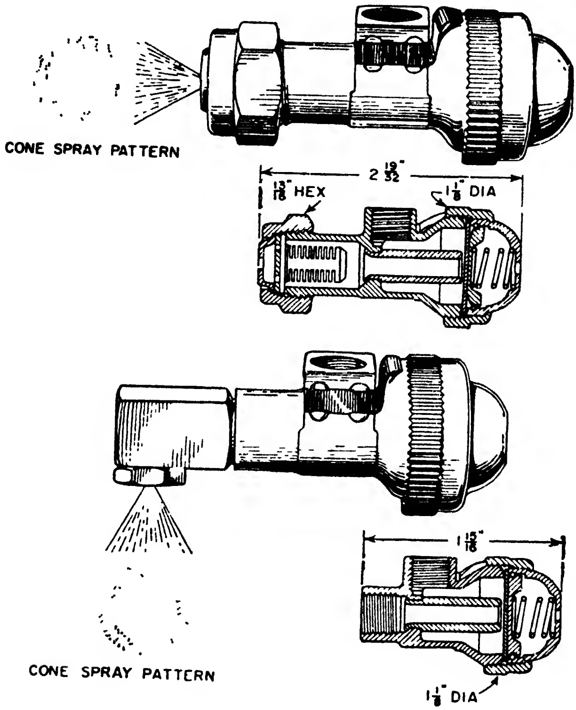

Fig. 14-21. Two types of sprayer nozzles for aircraft· *top*, discharge at tip and in line with air stream; *bottom*, discharge on side and at right angles to air stream. (*Spraying Systems Co.*)

The average contract price for airplane spraying is 35 to 40 cents per gallon.

DUSTING EQUIPMENT

Dust insecticides and fungicides were first applied to plants by placing the dust in a thinly woven bag. The bag was then shaken over the plants. Later, bags were attached to each end of a pole so that a man riding a horse or mule, at a trot, along the rows of plants could hold the pole and

suspended bags over the rows and shake the dust from the bags onto the plants. Hand dusters equipped with a hopper, fan, and discharge tubes were invented by W. R. Monroe of Unionville, Ohio, in 1895. This duster (called Sirocco) was converted to a horse-drawn and traction-powered machine about 1897. A gasoline engine was adapted to power-operate this duster in 1911. About 1920, hoppers, fans, and discharge tubes were mounted on horse-drawn carts to apply chemical dusts to cotton. Long, flexible metal tubes were arranged on booms so the dust was discharged over six to eight rows of plants. Tractor-mounted power field dusters were developed in the late 1920s and early 1930s.

Fig. 14-22. Six-row tractor-mounted power duster in operation. (*Gustafson Mfg. Co., Inc.*)

Types of Dusters. Dusting equipment can be generally classified as field and orchard power dusters.

Tractor-powered Field Dusters. Figure 14-22 shows a dusting unit mounted upon a platform bolted to the rear of a tractor and operated by the power take-off. Operating the tractor in high gear makes it possible to dust a larger acreage than with horse-drawn machinery of equal row capacity. Auxiliary engines are used on some tractor-mounted dusters to obtain more uniform power. The schematic drawing in Fig. 14-23 shows an agitator in the bottom of the hopper to keep the dust in a fluffy condition in order that it will be metered out uniformly through the feed system into the air stream. Tractor-drawn trailing dusters with power take-off drive and auxiliary-engine drive are available. Dusters of this type are easily attached to and detached from the tractor. They are suitable for small farms where one tractor is used to perform all cultural operations.

Tractor wheel fenders are essential when either tractor-mounted or trailing sprayer and duster are used to apply chemicals to tall, wide-spreading cotton plants.

Orchard Power Dusters. Most orchard dusters are operated by an auxiliary engine. Others can be mounted on the rear of a tractor or on a trailer and driven from the power take-off. Power units can also be mounted on the floor of a truck, thus saving the cost of a special sprayer

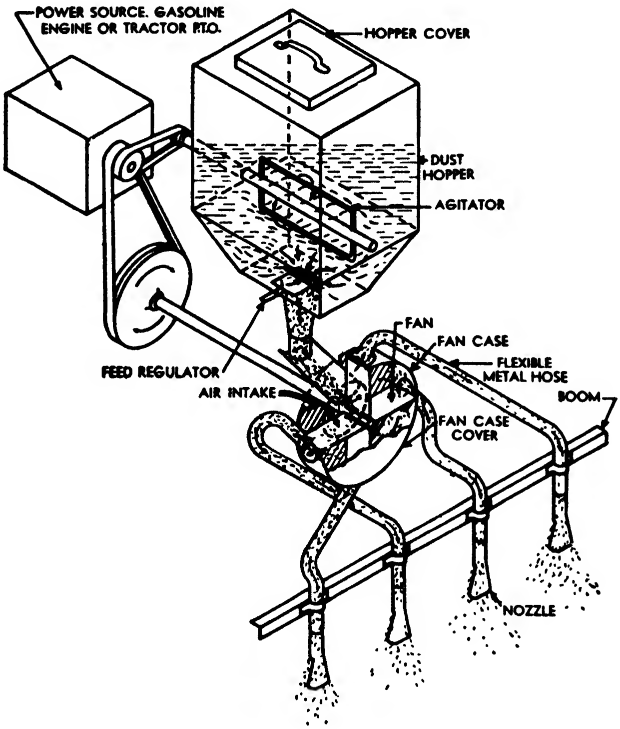

Fig. 14-23. Schematic drawing of typical power duster. (*National Sprayer and Duster Association.*)

chassis. Orchard dusters have only one large flexible metal hose, which can be turned to direct dust in any direction.

Electronic Duster. A company in Texas claims to have developed an electronic attachment for field dusters. The following is a statement from the company's trade literature:

> Transistor power supply runs off of 6 or 12 volt tractor battery. Draws 3 amps, steps voltage up to 12,000 volts. This voltage fed into a special nozzle creates an electric wind. Dust passing through picks up an electrical charge which will magnetize the dust particles. The magnetized

dust will go to the growing plant of opposite polarity, will coat plant with thin even coat of dust from top to bottom making it impossible for insects to crawl without making contact with the dust. Dust can be applied any time. Not necessary to wait for dew or calm weather.

Fig. 14-24. Airplane applying chemical dust. (*Photo by W. R. Smith.*)

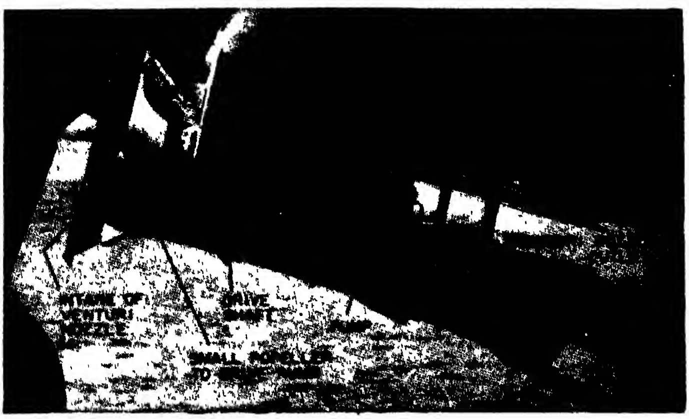

Fig. 14-25. Side view of venturi nozzle for aircraft showing propeller and worm-gear drive for agitator in hopper. (*Delta Air Lines, Inc., Agricultural Division.*)

Research is being conducted to determine if this method of applying insecticides will increase yields.

Airplane Dusters. Airplanes have been successfully used to apply dust to both field crops and orchards (Fig. 14-24). A hopper capable of holding 500 pounds of calcium arsenate is built inside the fuselage in the space ordinarily occupied by the front seat. The opening in the top

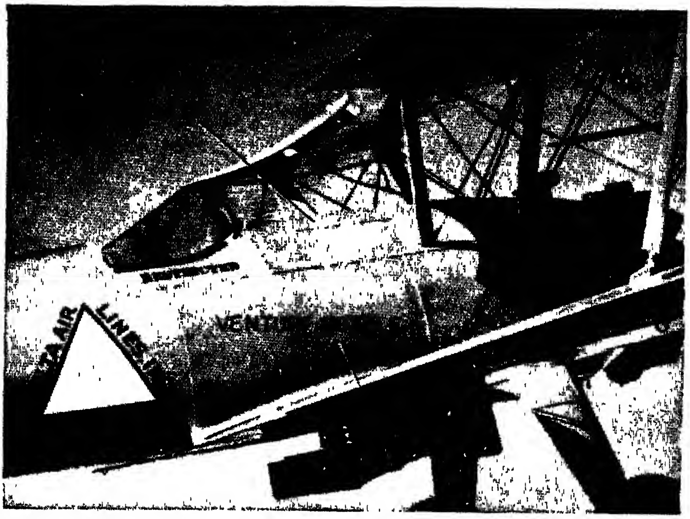

Fig. 14-26. Section of airplane fuselage showing location of venturi nozzle. (*Delta Air Lines, Inc., Agricultural Division.*)

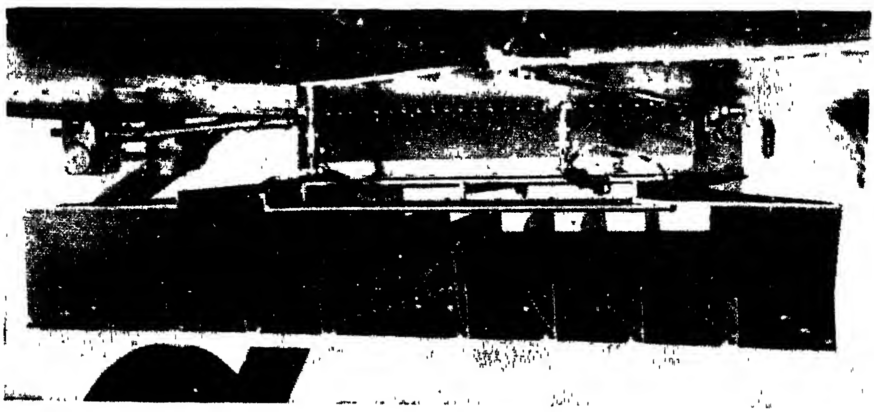

Fig. 14-27. Close-up rear view of dusting-seeding-fertilizing venturi with curved vanes to spread material being distributed. (*Delta Air Lines, Inc., Agricultural Division.*)

for filling is covered by a close-fitting lid, hinged in front. The dust in the hopper is stirred just above the outlet at the bottom by an agitator driven by a small propeller mounted on the wing (Fig. 14-25). The feed consists of an opening across the width of the fuselage. A slide covering the opening is operated by the pilot. The amount the feed valve is opened regulates the flow of dust and determines the poundage applied per acre. A venturi nozzle (Figs. 14-26 and 14-27) is mounted underneath the

fuselage and the dust outlet. The rear end of the nozzle is tipped slightly downward. The blast of air created by the plane's propeller rushes through the venturi nozzle at a high velocity, catching the dust and discharging it in a whirling cyclindrical column that spreads and settles on the plants. It is claimed that the high velocity of air through the nozzle creates a partial vacuum in the feed opening, which aids the flow of dust.

An airplane can dust approximately 350 or more acres per hour, which is many times the acreage that can be dusted with any other type of machine in the same length of time. Data kept on the time required for airplane operations show the average loading time to be 3 minutes 5 seconds, average flying time per load 14 minutes 30 seconds, and the average dusting time per load 4 minutes 45 seconds. About one-third of the time is spent in actually dusting, the remainder being consumed in turning, and flying to and from the landing field. The average contract price in 1963 for applying poisons to cotton was 4.5 cents per pound. The farmer furnished and paid for the poison.

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QUESTIONS AND PROBLEMS

1. Explain the classification of spray materials.
2. Explain the functions of a sprayer.
3. Explain the differences in the various types of sprayers.
4. Describe the different types of pumps for sprayers.
5. Explain the functions of a pressure regulator.
6. Explain the steps in calibrating a sprayer.
7. A farmer wishes to apply 5 gallons of spray per acre to a crop planted in rows spaced 40 inches apart, with a sprayer traveling 5 m.p.h. What size nozzles should he use when using: (*a*) one nozzle per row, (*b*) two nozzles per row, and (*c*) three nozzles per row?
8. Discuss the effect of nozzle type and arrangement on the control of cotton insects.
9. Explain the various spray patterns that can be obtained with aircraft sprayers. What effect do cross winds have on the spray pattern?
10. Explain the various types of dusters.

FERTILIZING EQUIPMENT

15

Fertilizers are required where soils are deficient in plant food elements. When land is planted to crops over a long period of years, the plant food elements are reduced and yields of crops are lower. Sandy soils lose plant food elements rapidly because they are leached out by heavy rainfall or applications of irrigation water. Some clay soils in low-rainfall areas lose plant food elements much more slowly than the sandy soils. It is now recognized that higher yields can be expected from most soils in all areas if the right type of fertilizer is properly applied.

Fertilizer can be applied to the soil in several forms, such as barnyard manure, granular and pelleted fertilizers of various formulae, and fertilizers in liquid and gaseous form. Special equipment is required for the handling of these types of fertilizers, which are applied to the soil and crop in various ways at different stages of culture. For example, barnyard manure is usually broadcast over the land with a *manure spreader* before seedbed preparation. It is then worked into the soil, either by plowing or by disk harrow.

MANURE SPREADERS

The manure spreader is a machine for carrying barnyard manure to the field, shredding it, and spreading it uniformly over the land. This type of machine should be on every farm that produces several tons of manure per year. Manure spreaders can be classified as horse-drawn and tractor-drawn types. Horse-drawn manure spreaders are mounted on four

wheels and are provided with a tongue and eveners. They are ground-driven.

The mechanism of a ground-driven manure spreader is operated by sprockets and chain from the wheels supporting the spreader. The power- or power-take-off-driven type is designed to drive from the tractor power take-off having 540 r.p.m. The power take-off shaft is telescoping so that it automatically adjusts for changes in length on turns. The shaft connects to the center of the spreader box. A chain transmits the power to a drive shaft that extends backward along the side of the box to a sealed gear drive connected to the spreader drive mechanism.

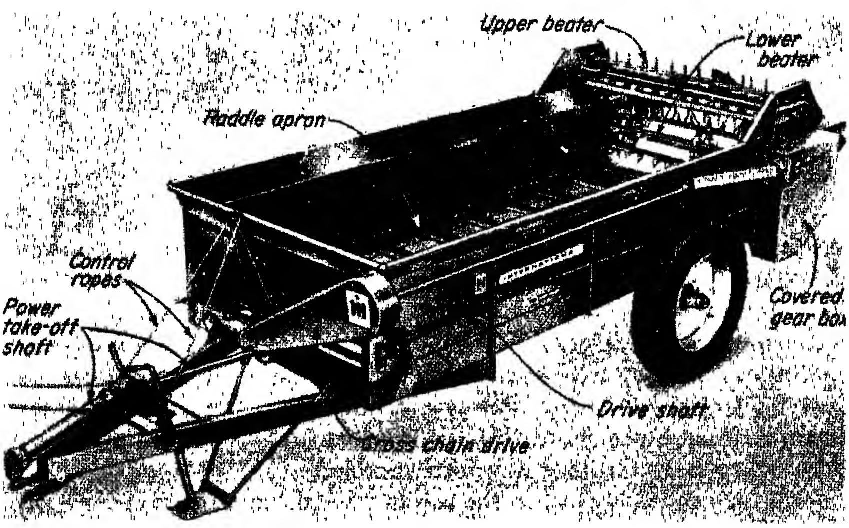

Fig. 15-1. Tractor-trailer power-take-off-driven manure spreader. (*International Harvester Company.*)

The *tractor-drawn* power-driven spreaders are generally mounted on two rubber-tired wheels on an axle located slightly to the rear of the box, so that part of the weight of the spreader will be carried by the tractor (Fig. 15-1).

The principal parts of the manure spreader are the frame, the box, the conveyor, the beaters, and the widespread.

The Frame. Since manure is very heavy and at least a ton or more is loaded on the spreader for each trip to the field, a substantial yet comparatively light frame is required. The side rails on all spreaders should be made of a good grade of channel steel properly reinforced and braced.

The Box. The bottom and sides of the manure spreader box may be made of tongue-and-groove creosoted wood, of marine plywood, or of 12- to

14-gage sheet steel. The side flares consist of heavy sheet steel. One company used armored steel for the flares to resist damage by blows from the buckets of power loaders. The front of the box is closed by an inclined endgate, while the rear part of the box is open to the beaters. The rear end of the box is 1 to 2 inches wider than the front end to reduce pressure on the sides. This also reduces friction as the load moves to the rear.

The *capacity* of a manure spreader box is rated in bushels (by volume), according to a standard formula adopted by the American Society of Agricultural Engineers (Fig. 15-2).[1] Manure spreaders are available in sizes ranging from 45 to 175 bushels.

Some manufacturers provide a high side so the box can be converted into a self-unloading or tight forage box (Fig. 15-3).

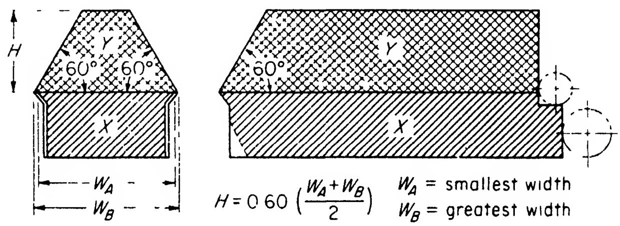

Fig. 15-2. Method of measuring and formula for calculating the capacity of a manure-spreader box (*ASAE Standard: Agr. Engin. Yearbook*, 1962.)

The Conveyor. The manure in the box is moved to the rear by an endless double chain-and-slat conveyor or apron (Fig. 15-4). The angle iron bars used for the conveyor slats are riveted to the chains with the outside leg or high side facing to the rear of the box. The manure is deposited in the box on the conveyor; then as the conveyor moves, it carries the manure with it to the rear of the machine, where it comes in contact with the beaters.

The conveyor operates very slowly. The minimum travel per revolution of the main drive wheel is about 1 inch, while the maximum is about 3 inches. The rate of travel is controlled by a lever placed conveniently for the driver. From five to twenty loads can be spread per acre. The tension of the conveyor chain can be adjusted by a setscrew arrangement on each end of the front conveyor shaft.

Conveyor Drive. A ratchet and pawl arrangement is the standard device for driving the conveyor chain of a manure spreader (Fig. 15-5). As the feed cam raises the rocker arm, it causes the feed pawl to engage the teeth on the ratchet wheel and turn it. The number of teeth engaged by

[1] *Amer. Soc. Agr. Engin. Yearbook,* 1963.

the feed pawl at a stroke is regulated by a stop pawl. This in turn regulates the speed of the conveyor and the volume of manure distributed. The adjustment of the feed pawl is controlled by a lever placed conveniently for the driver. The lever is connected to the feed pawl by a long rod and can be shifted to any position without stopping the machine.

The power for driving the apron and beaters is derived from ground traction of the spreader wheels or from the power take-off of the tractor.

The Lower Beater. The lower beater is placed just to the rear of the conveyor to beat, tear up, and spread the manure from the rear of the

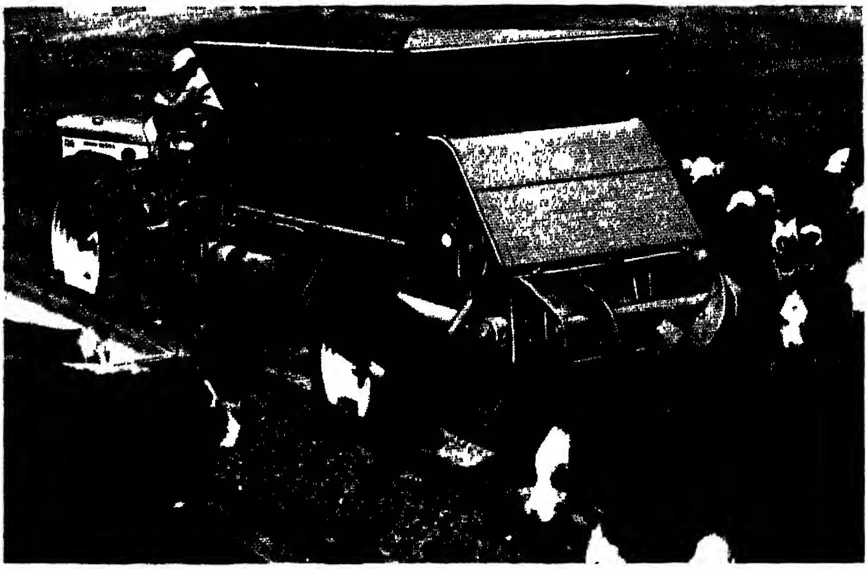

Fig. 15-3. Manure spreader converted into a self-unloading forage box. (*Deere & Co.*)

spreader (Fig. 15-6). It must be substantial because it must spread all kinds of manure in various states of physical condition. It should have good strong bearings of the self-aligning or roller type. The beater has steel bars through which the teeth are fastened. Some teeth are riveted in, while others are held in place by nuts.

The beater revolves in the opposite direction to the main wheels. It is, therefore, necessary to have some arrangement to give it this reverse motion, which will be discussed under Beater Drive. The beater should revolve at a comparatively high rate of speed; the ratio is usually about 6 or 7 to 1; that is, a beater revolves about seven times when the main wheel revolves once.

Beater Drive. The chain is the common method of driving the beaters on ground-driven manure spreaders. A large drive sprocket is mounted

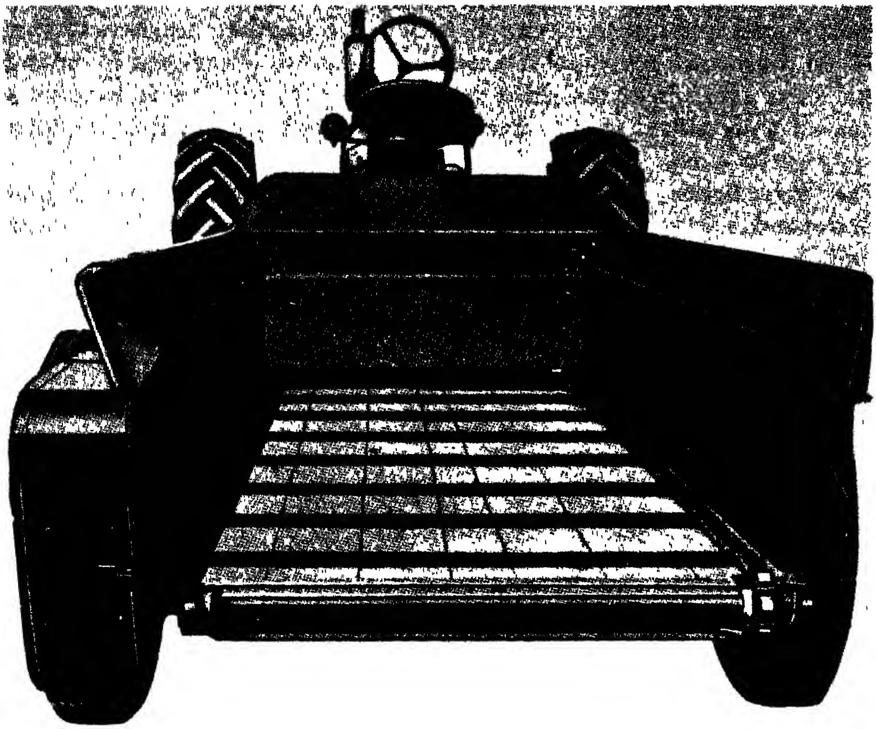

Fig. 15-4. Rear view of manure-spreader box showing endless double chain and slat conveyor in place on box bottom. (*New Holland Machine Co.*)

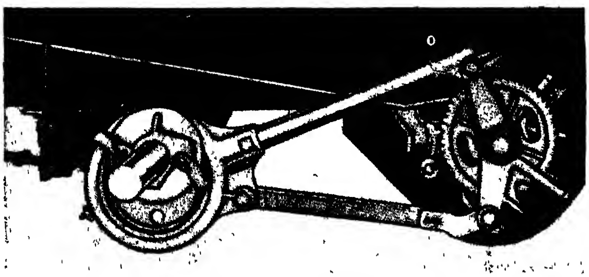

Fig. 15-5. Apron drive using eccentric device to operate the ratchets which slowly revolve the ratchet gear and thus move the apron over the box bottom at the rate desired.

rigidly on the main axle. In Fig. 15-6, the drive chain passes around sprockets on the end of the upper beater shaft and the main beater shaft and around a movable idler sprocket. The chain does not pass around the drive sprocket. As the movable idler sprocket is lowered, the bottom part of the drive chain is lowered onto the drive sprocket. This will cause the

beaters and widespread device to turn in the opposite direction to that of the main drive sprocket. The machine is thrown out of gear by raising the drive chain from the drive sprocket (Fig. 15-6). This is done by a control lever placed on the front of the box and connected to the idler sprocket by a rod.

The Upper Beater. Most manure spreaders have an upper beater placed above and a little to the front of the main beater (Fig. 15-6). This beater aids the lower beater in tearing up and pulverizing the large flakes that are encountered.

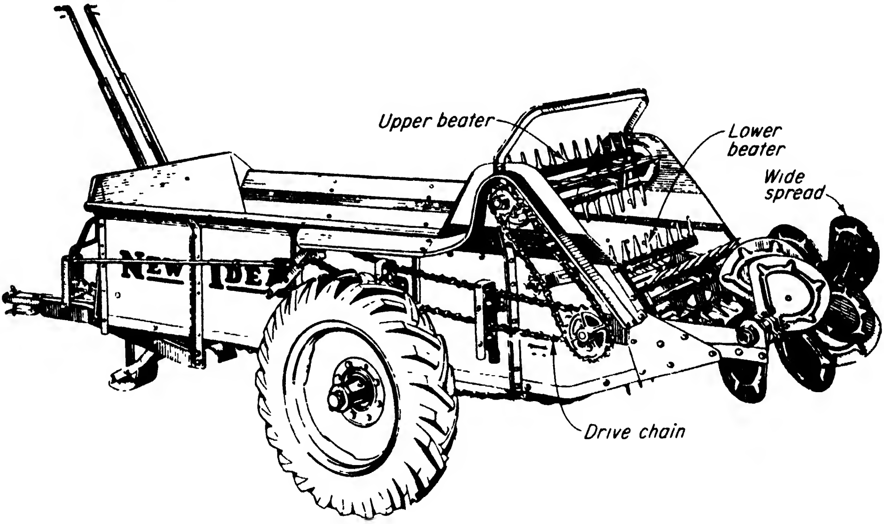

Fig. 15-6. View of ground-powered manure spreader showing position of beaters and widespread. It also shows the drive chain in raised out-of-gear position. (*New Idea Farm Equipment Co., Div. Avco.*)

Widespread Device. To prevent the manure being spread too thickly directly behind the center of the machine, a widespread device is used (Fig. 15-6). This also spreads the manure wider than the machine and makes it unnecessary to lap the loads. The device consists of spiral auger-like steel blades. One-half of the spiral is set to throw to the left, while the other half is set to throw to the right.

The manure is thrown backward by the beaters against the revolving spirals, which throw it backward and outward and spread it uniformly over a width of 7 or 8 feet. The widespread beater is driven by a chain from the main or auxiliary beater shafts.

Some models of manure spreaders use only the widespread for beating and spreading the manure. The upper and lower beaters have been eliminated (Fig. 15-7).

Loading the Spreader. It is considered the better plan to start loading at the front end and finish at the rear end. The manure is torn up and broken to pieces more easily when the load is put on in this manner.

Mechanical Loaders. When manure is spread mechanically, more time is consumed in loading than in any other operation. This is also the hardest work. Mechanical loaders are available, which eliminate the necessity of loading with a pitchfork (see Chap. 24).

GRANULAR-FERTILIZER DISTRIBUTORS

Dry, granular chemical fertilizers have for many years been the most common type of fertilizer used by farmers. Such fertilizers are of many

Fig. 15-7. Showing the drive shaft and apron and beater drive for a power-driven manure spreader. (*International Harvester Company.*)

kinds and vary from highly concentrated chemicals, which must be used in small quantities, to a rather low-grade mixture used in large quantities. A fertilizer distributor is required which will distribute varying amounts of fertilizer in almost any physical and mechanical condition and place it in the soil so that it will not injure the seed. It is difficult to design a machine that will meet such a wide range of requirements. The proper application of fertilizer is the key to efficient fertilizer use.

Location of Fertilizer in Relation to the Seed. A committee on fertilizer application of the American Society of Agronomy recommended that all fertilizer attachments on planting and seeding machinery be designed to prevent contact between seed and fertilizer.

A joint committee on fertilizer application, representing the American Society of Agronomy, the American Society of Agricultural Engineers, The National Fertilizer Association, and the National Association of

Farm Equipment Manufacturers, adopted the following statement on fertilizer application:

> Contact of fertilizer with the seed, except when fertilizer is used in very small amounts, tends to depress and delay germination and may even prevent it. The extent of this delay or depression varies with the materials used in the fertilizer, with the moisture content of the soil, with the crop grown, and with the quantity of fertilizer applied. The recommended fertilizer placement is 2 to 3 inches to the side of the row and 3 to 4 inches below the soil surface. The location of the fertilizer will depend upon the amount and kind of fertilizer and the row spacing.

Accepting the above statements, we find that the fertilizer can be applied as hill applications with hill dropping of the seed or can be drilled when the seed are drilled. For the small grains, it can be either drilled or broadcasted. To accomplish the desired results in each case, many different attachments are available.

Fertilizer Attachments. Operating costs can be reduced when attachments that permit dual operations are used in connection with various types of equipment. Fertilizer attachments are available for most tractor-mounted planters and cultivators. Attachments are also available for grain drills and some types of plows.

Attachments for Row Planters. Fertilizer attachments have been designed to work in conjunction with most tractor planters, both the drill and check-row types. Figures 12-2, 12-11, 12-16, and 12-18 show tractor planters equipped with fertilizer attachments. Figure 15-8 shows a split-row boot for check-row planter furrow opener and how the fertilizer is placed on each side of the hill of seed.

Fertilizer attachments are available for bean, beet, and potato planters. Figure 12-30 shows a potato planter equipped with fertilizer attachment. A special-type fertilizer feed used to meter out fertilizer for application to potatoes and the placement of the fertilizer in relation to the seed are shown in Fig. 15-9.

Grain-drill Fertilizer Attachments. Fertilizer attachments for grain drills consist of a specially constructed hopper having a partition extending lengthwise through the middle (Figs. 12-40 and 12-41). The planting unit is in the front half of the box, while the fertilizer unit is in the rear half.

Many fertilizer drills release both seed and fertilizer through the same tube. This is not good practice, because the seed are in direct contact with the fertilizer and germination may be affected. A better method is to release the fertilizer through separate tubes which will place the fertilizer in the drills above the seed, as shown in Fig. 12-41. A pasture drill equipped with a fertilizer attachment is shown in Fig. 12-50.

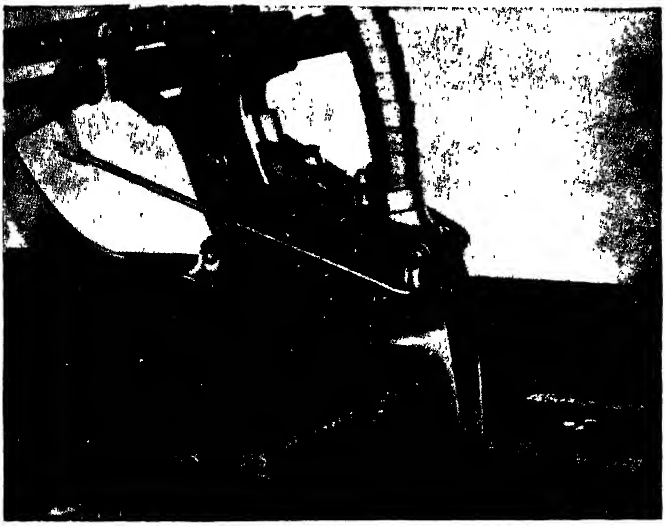

Fig. 15-8. A portion of the soil cut away to show how the split-row boot places the fertilizer on each side of the hill of seed. (*International Harvester Company.*)

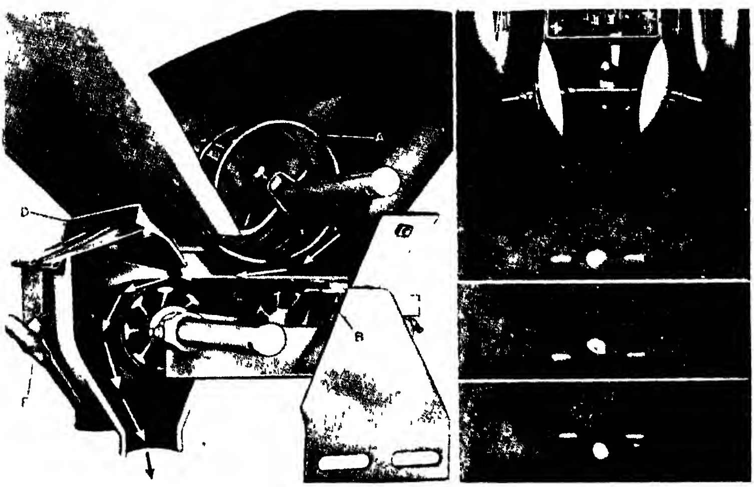

Fig. 15-9. The view at left shows a belt-type fertilizer feed. The view at the right shows how bands of fertilizer can be placed at the seed level, above the seed, or below the seed level. (*Deere & Co.*)

Fertilizer Attachments for Cultivators. Fertilizer attachments for tractor-mounted cultivators to apply granular fertilizer as a side dressing to growing crops are shown in Figs. 15-10 and 15-11.

Fertilizer Attachments for Chisel Plows. Fertilizer attachments are available for the chisel-type plow. Fertilizer can be applied as a preplanting operation and can also be applied to row crops as a side dressing and to pasture lands.

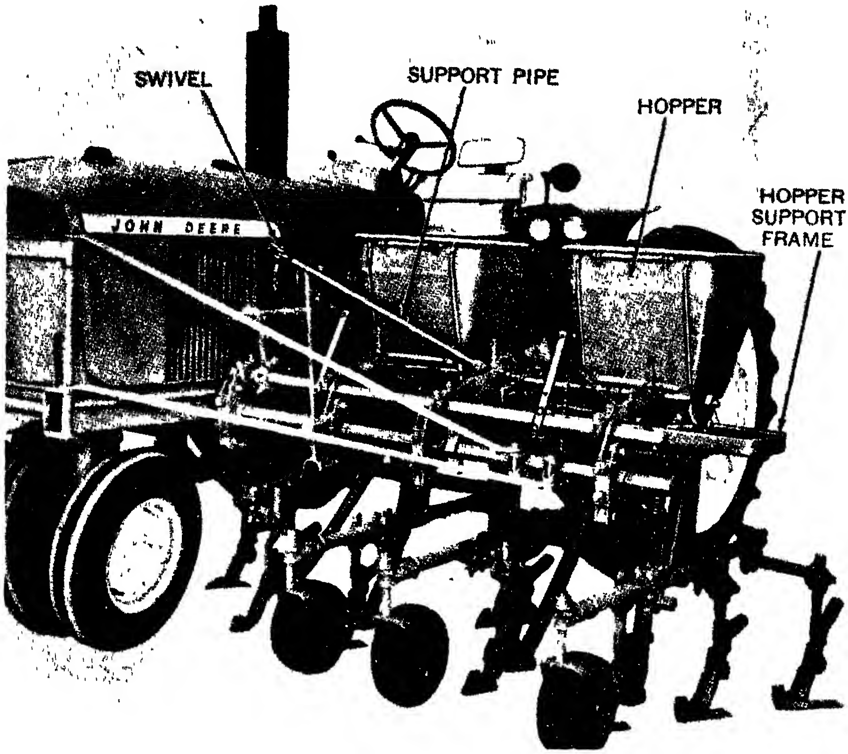

Fig. 15-10. Fertilizer attachment for side dressing with cultivator. (*Deere & Co.*)

Broadcast Fertilizer and Lime Distributors. Figure 15-12 shows machines suitable for broadcasting either lime or fertilizer. Usually, a wire screen is used in the top of the hopper to remove large lumps and prevent clogging of the feeds. Some models drop the lime or fertilizer on a scattering board, which deflects and scatters the material so that it will be more thoroughly broadcasted. A trailing-endgate type of fertilizer and lime spreader is shown in Fig. 15-13. It is similar in construction to the endgate seeder, with the exceptions that the hopper is flush with the wagon box and the revolving scattering discs are much closer to the ground.

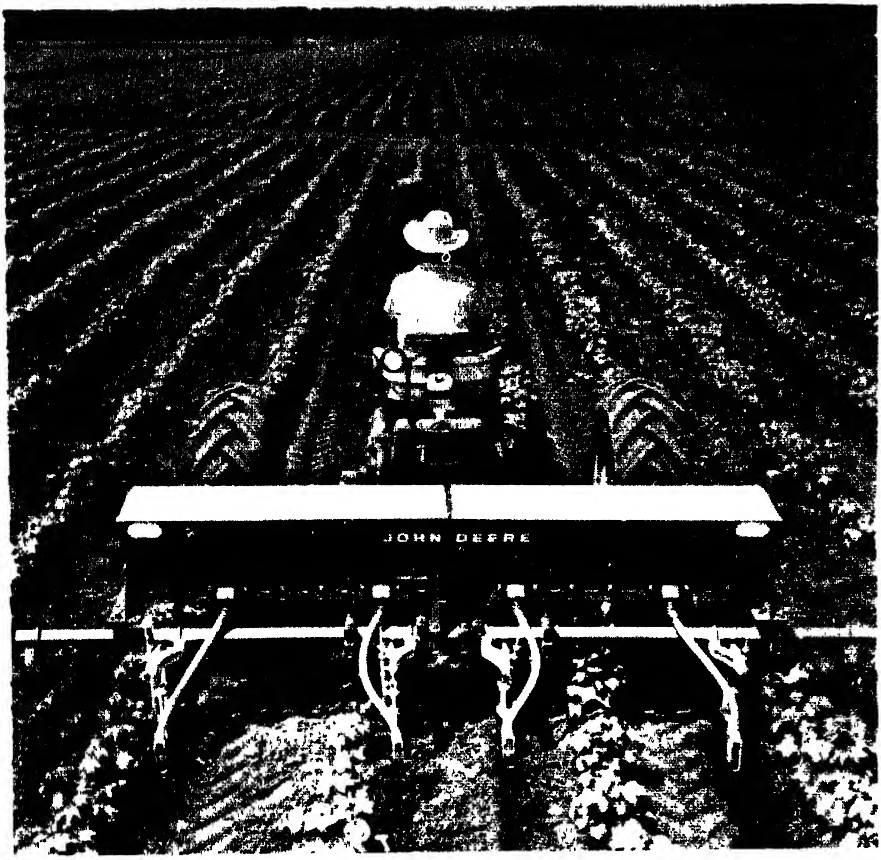

Fig. 15-11. A four-row fertilizer distributor applying fertilizer to the side of the rows of cotton. (*Deere & Co.*)

Fertilizer Feeds. The efficiency of any fertilizer-distributing machine depends upon the proper handling of the fertilizer by the feeding mechanism. A number of factors will influence the efficiency of the feed, some of which are:

1. Climatic conditions, based on temperature and rainfall
2. Amount of fertilizer to be applied
3. Kind of fertilizer:
   a. Chemical composition
   b. Physical state

Many attempts have been made to design a fertilizer feed that will handle any and all kinds of fertilizer, distributing any desired quantity. As a result, several different types are being used. The operator's manual

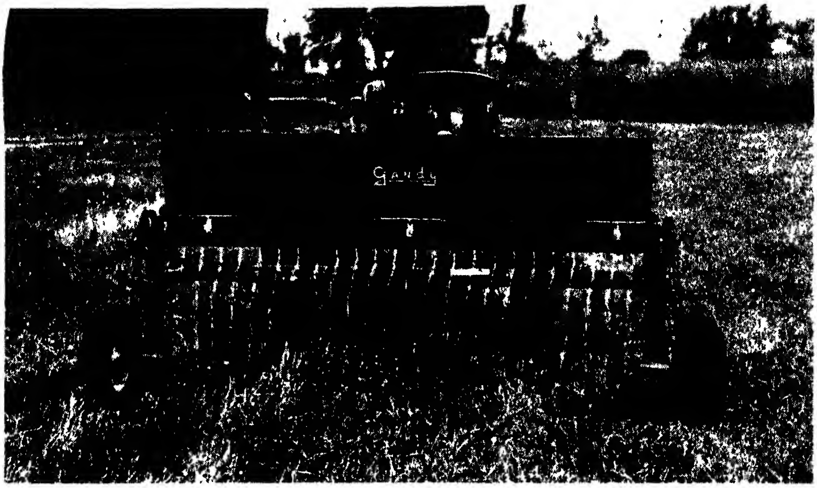

Fig. 15-12. Tractor-mounted broadcast fertilizer and dry chemical distributor that can be adjusted for height. Different types of furrow openers and soil-mixing tools are available as attachments. (*Gandy Company Inc.*)

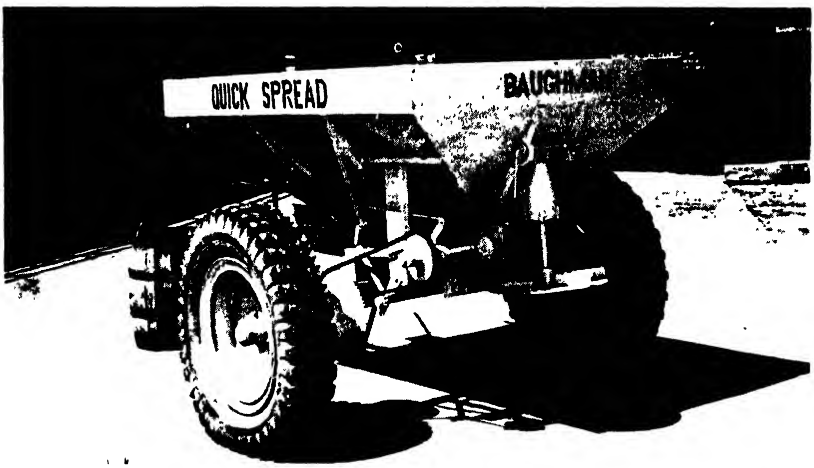

Fig. 15-13. Trailing ground-driven broadcast fertilizer and lime spreader. (*Baughman Mfg. Co., Inc.*)

supplied by the manufacturer should be studied so that the method of regulating the quantity of fertilizer applied per acre can be fairly accurately followed. The manuals give instructions on how to adjust the feed to change the rate of application and the care and maintenance of the fertilizer equipment. A belt-type feed is shown in Fig. 15-9. Other types of feeds use metering notched discs, the star-wheel feed, and the bar reel feed.

EQUIPMENT FOR APPLYING GAS AND LIQUID FERTILIZERS

Liquid fertilizers are available in high- and low-pressure and nonpressure forms. Anhydrous ammonia is a high-pressure fertilizer, while a mixed fertilizer containing nitrogen, phosphate, and potash in solution is a nonpressure fertilizer. Most liquid fertilizers are applied below the surface of the soil, but some types can be sprayed on the foliage of the plants.

Anhydrous Ammonia. The use of anhydrous ammonia as a source of nitrogen for cotton was started by some farmers of Mississippi in March, 1947. By 1949, approximately 2 million acres in the Cotton Belt were fertilized with anhydrous ammonia.[2] It has become a popular source of nitrogen for many crops and orchards, as it is the cheapest source of nitrogen available.[3]

Anhydrous ammonia is a colorless alkaline gas at normal temperatures and atmospheric pressure and contains 82 per cent nitrogen. It, however, exists as a liquid at −28°F. and boils at this temperature; as a liquid it has a density of 42.57 pounds per cubic foot. It is handled in commerce as a compressed liquid and stored under pressure. At higher temperatures the vapor pressure increases rapidly. For example, at 50°F. it is 74.5 pounds per square inch, at 100°F. it is 197.2 pounds per square inch, and at 125°F. it is 293.1 pounds per square inch. A gallon of anhydrous ammonia weighs 5 pounds and contains 4.1 pounds or 82 per cent nitrogen.

Anhydrous ammonia is inflammable when mixed in proportions of 16 to 25 per cent by volume with air. It is corrosive to copper, copper alloys, aluminum alloys, and galvanized surfaces. Ammonia vapors are stifling, and high concentrations may burn, blind, strangle, or kill. Therefore, it must be handled with caution. It must be shipped, stored, and handled on the farm in tanks in accordance with Interstate Commerce Commission regulations and accepted state safety codes. Bulk storage is usually handled by dealers.

Tanks for transporting anhydrous ammonia to the farm usually have a capacity of 500, 1,000, or 3,000 gallons. They can be mounted on motor trucks, motor-truck trailers, or other types of trailers. These tanks must be handled in accordance with state rules and regulations.

Field Tanks for Anhydrous Ammonia. It is recommended that farmers who use propane gas for flame cultivators *do not* use these tanks for

[2] William Baker Andrews (ed.), *Cotton Production, Marketing, and Utilization*, William Baker Andrews, State College, Miss., 1950.

[3] Harold T. Barr, Anhydrous Ammonia Equipment, *La. Agr. Expt. Sta. Bull.* 462, 1952.

anhydrous ammonia, as they usually have brass and bronze fittings. Ammonia may cause brass or bronze fittings to develop internal checks. A slight strain, blow, or twist to a brass fitting affected by ammonia might cause the fitting to break off, release the ammonia, and injure the operator. Tractor tanks should have steel fittings, valves, and gages to handle anhydrous ammonia safely. Tractor-mounted tanks (Fig. 15-14) should have a capacity of 80 to 110 gallons. Large trailer-mounted tanks may have a capacity up to 150 gallons. Figure 15-15 shows a typical small trailer tank and application parts. All tanks should be equipped with the following fittings:

1. Three-hundred-pound pressure gage.
2. Liquid outlet valve screwed directly into the shell of the tank and connected to a pipe extending down inside the tank to within ½ to ¾ inch of the bottom. The bottom end of the pipe should have a 1/64-inch mesh strainer.
3. Safety or pop-off valve of ¾ to 1 inch set for 250 pounds per square inch pressure.
4. A ¾- or 1-inch automatic back-seating liquid-filling valve.
5. A liquid-level gage.
6. Vapor return valves, ½ or ¾ inch, with a short pipe extending into the tank to prevent filling to over 85 per cent water capacity. This valve is also used for gas escape in bleeding.

Metering Devices. A reliable type of meter recommended and guaranteed by a dealer should be installed on all anhydrous ammonia applicators. The meter regulator should be calibrated with ammonia and the same hose and applicator feet that will be used with the outfit. The metering device should be designed to withstand pressures of 150 to 250 pounds per square inch on the high side and 0 to 90 pounds per square inch on the low-pressure side. The meter regulates the flow of anhydrous ammonia to the desired rate per acre. The pressure in the tank will be reduced as the ammonia is used, but on the other hand midday sunshine will cause a rise in temperature and pressure.

A quick-cutoff valve should be installed between the tank shutoff valve and the meter regulator. This will permit closing the quick-cutoff valve without disturbing the meter setting, during turning at row ends.

Applicator Chisel Knives. The applicator is a ground-working chisellike knife having a small ⅝-inch pipe welded to the rear side or a drilled hole to conduct the ammonia 5 to 6 inches below the soil surface (Fig. 15-15). It is also called an *applicator foot, applicator shank,* or *applicator knife.* There are many types with different shapes, curves, and accessories. The applicators are attached to the regular cultivator frames or to special frames. Applicators may be tractor-mounted or trailing.

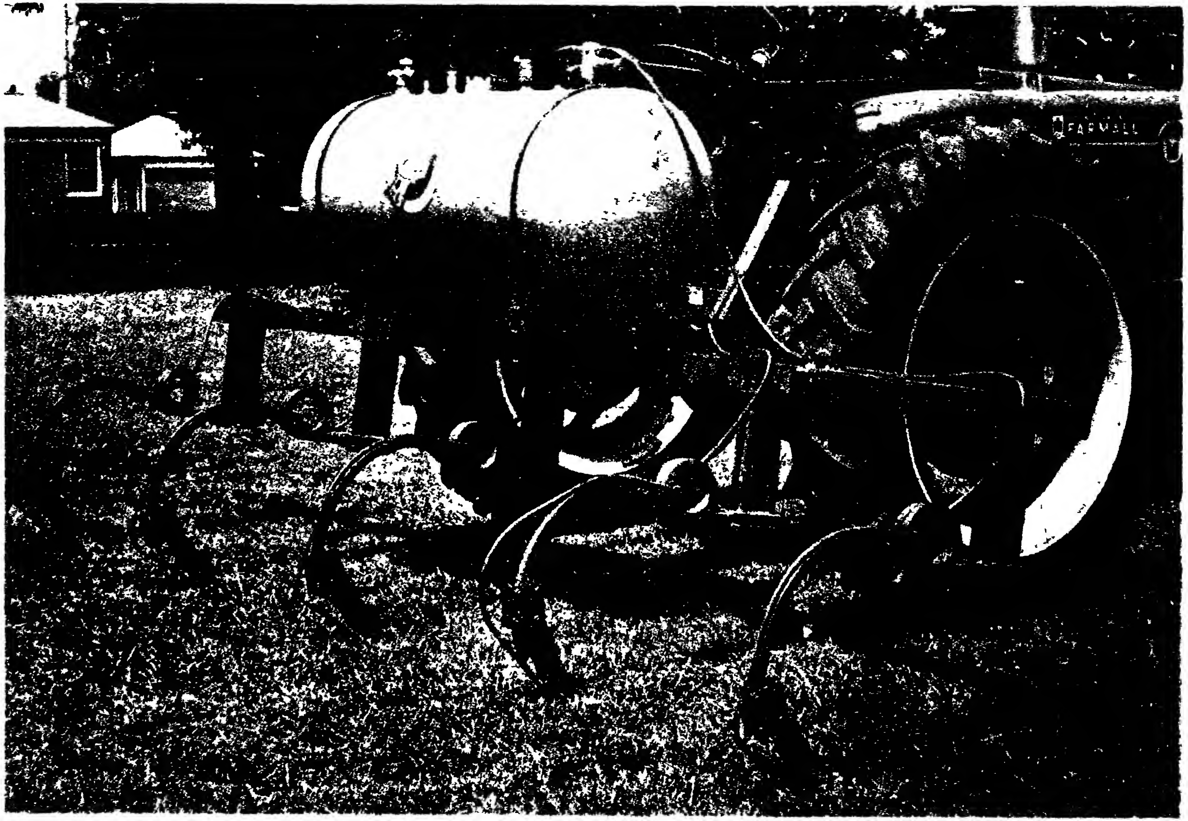

Fig. 15-14. Tractor-mounted anhydrous ammonia applicator. (*Gotcher Engineering and Mfg. Co.*)

Barr states that

> The applicator should be as narrow as possible, have sufficient strength to prevent breakage or be equipped with a single trip, be hard surfaced to prevent undue wear, provide for easy and secure attachment of anhydrous ammonia hose, and the final hole in the applicator should be constructed so as to deliver the ammonia without creating back pressure or without being plugged up easily by soil.

Some means, such as a wheel or disk blade attached to the beam slightly to the rear of the applicator, should be provided to close the

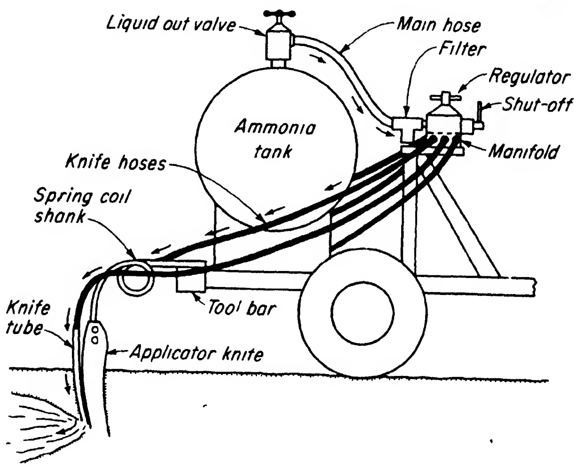

Fig. 15-15. Typical small trailing anhydrous ammonia applicator.

furrow made by the applicator and prevent the escape of the ammonia from the soil. Some applicators are designed so that liquid phosphate can be applied in the same furrow but through separate tubes.

The applicators should be spaced to suit the crop row spacing. Generally there is one applicator per row. When ammonia is applied to small grains, the applicators are spaced about 16 inches apart.

Rubber hose should be used for the feed lines from the tank to the applicator to prevent the possibility of ice forming and plugging the lines. Expanding ammonia causes ice to form on iron pipes, and the feed line should extend as near the soil as possible.

Calibrating Anhydrous Ammonia Equipment. Manufacturers check the equipment carefully before it leaves the factory, and many farmers may think it unnecessary to recheck it when it is installed on their tractor.

However, there are many things that can happen between the factory and the farm, and the equipment should be rechecked for accuracy of quantity applied per acre.

A simple method of calculating the pounds or gallons of ammonia applied per hour is as follows: Operate the equipment in the field at a set speed over a measured distance two or three times. Take the average travel time for the distance, then apply the following formula:

$$\frac{\text{Ft. per sec.} \times \text{sec. per hr.} \times \text{no. of rows} \times \text{row spacing} \times \text{lb. of N per acre}}{\text{Sq. ft. per acre} \times 0.82}$$

For example, 50 pounds of nitrogen per acre is to be applied with four-row equipment (one applicator to each 40-inch row spacing). The trial runs gave a travel rate of 300 feet per minute, or $^{300}/_{60} = 5$ feet traveled per second.

$$\text{Lb. of ammonia per hr.} = \frac{5 \times 3{,}600 \times 4 \times 3\tfrac{1}{3} \times 50}{43{,}560 \times 0.82} = 352.8$$

$$\text{Gal. of ammonia per hr.} = 70.6$$

Manufacturers of metering devices furnish charts that give the correct setting of the valves they manufacture. Some of the charts show the number of pounds of anhydrous ammonia per hour, while others show the pounds of nitrogen per acre with tractor speed and settings for the amounts given in the chart. These are calculated for different orifice sizes, which may range from $^3/_{32}$ to $^{11}/_{64}$ inch.

Cost of Anhydrous Ammonia. The cost will vary from year to year and from one area to another. Quotations can be obtained per ton or per pound of nitrogen based on 82 per cent nitrogen. Prices per pound of nitrogen may range from 5 to 13 cents. A four-row cultivator will, on the average, side-dress about 50 acres in 10 hours.

Some farmers may prefer to have anhydrous ammonia applied on a custom work basis. Barr gives the custom rates for applying anhydrous ammonia in Louisiana as follows:

1 to 24 acres, \$3.50 per acre
25 to 49 acres, \$3.25 per acre
50 to 150 acres, \$3.00 per acre
151 acres up, \$2.50 per acre

Cautions. Anhydrous ammonia should be handled with all safety rules and cautions in mind as it is irritating, will burn, and concentrated quantities will strangle and kill.

Buy equipment from well-established concerns who make products that will comply with all safety codes and state regulations.

Leave a small amount of ammonia in trailer and tractor tanks during periods they are not in general use.

Protect all valves on tanks and do not leave the valves open to outside air. Do not fill the tank with water or with any material other than anhydrous ammonia.

Do not use the ammonia tank for propane, or the propane tank for ammonia.

Do not use brass or bronze fittings. Use only extra-heavy steel fittings.

Do not weld on an ammonia tank.

Aqua Ammonia. When water is added to anhydrous ammonia to reduce the vapor pressure to atmosphere pressure it is termed *aqua ammonia.*

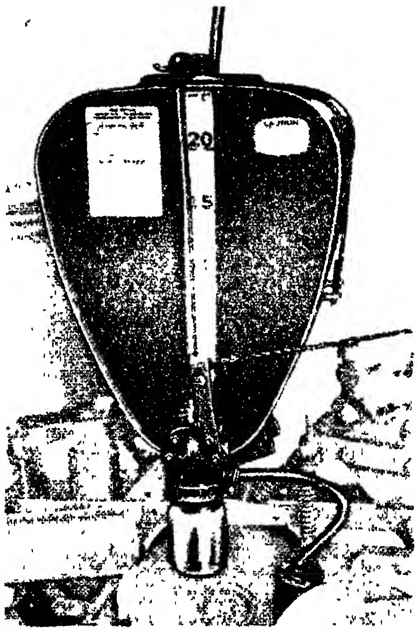

Fig. 15-16. Nonpressure liquid fertilizer tank used as an attachment for a planter (*Deere & Co.*)

This, then, is a low-pressure liquid fertilizer. It contains only about 20 to 25 per cent nitrogen. It must be handled with the same caution as anhydrous ammonia. Gravity feeds can be used if the material is discharged on the surface of the soil to be covered with soil-working blades. Pumps are required if the material is applied below the soil surface.

Mixed Liquid Fertilizers. When nitrogen, phosphorus, and potash are applied as a complete fertilizer, the combination is near chemical neutrality and is termed a nonpressure liquid fertilizer. It can be metered out by gravity flow, pump, or air pressure. It can be sprayed either with ground equipment or by aircraft. Figure 15-16 shows a nonpressure liquid fertilizer tank used as an attachment for a planter.

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QUESTIONS AND PROBLEMS

1. List the various forms of fertilizers.
2. Explain the essential features of a manure spreader and the function of the following: (*a*) conveying system, (*b*) upper and lower beaters, (*c*) widespread device.
3. Explain the drive mechanism for the conveyor on a manure spreader.
4. Explain the drive mechanism for the beaters and widespread device.
5 Discuss the placement of granular fertilizer in relation to the seed for row crops. What is the recommended location of the fertilizer in relation to the seed?
6. List and explain the various types of fertilizer attachments for planting equipment.
7. Define anhydrous ammonia, and explain its properties.
8. Discuss the equipment required for the application of anhydrous ammonia.
9. Explain the method of calibrating anhydrous ammonia equipment.
10. List several cautions in regard to the handling of anhydrous ammonia and the equipment.

HAY HARVESTING EQUIPMENT

16

Hay harvesting equipment consists of machines necessary in the various steps of hay making, while forage harvesting equipment consists of machines required for placing green succulent material into silos.

The principal machines required in making hay are mowers, rakes, and presses. In some areas, loaders, stackers, and barn hay-handling equipment are used.

MOWERS

The mower is designed to cut meadow grasses and special crops for hay; however, it has many other uses. Horse-drawn and tractor types of mowers are available in sizes to suit almost any requirement.

History of Development. Miller[1] stated that the development of the mower for cutting hay was closely associated with the development of the reaper. The first machines were used to cut either grain or grass. William F. Ketchum was the first to put mowers on the market as a machine distinct from the reaper. Ketchum's most important patent was dated July 10, 1847. The cutter bar of an endless chain of knives was soon abandoned, and Hussey's rigid bar substituted. Cyrenus Wheeler obtained a patent Dec. 5, 1854, on a machine that featured two drive wheels and a cutter bar joined to the main wheels. A patent was granted Cornelius Aultman, on July 17, 1856, containing basic principles of

[1] M. F. Miller, Evolution of Harvesting Machinery, *U.S. Dept. Agr. Expt. Sta. Bul.* 103, 1902.

mowers, such as the ratchet-pawl drive. By 1860, the mower was considered a practical machine.

Horse-drawn mowers were first used with tractors about 1910. Tractor-mounted mowers were available about 1930.

Tractor Mowers. There are several types of tractor mowers, classed largely by the way the mower is attached to the tractor. The principal types are the trail-behind, the integral rear-mounted, and the side- or central-mounted.

The Trail-behind Tractor Mower. This type of tractor mower is built as a unit assembly that can be easily attached to and detached from the

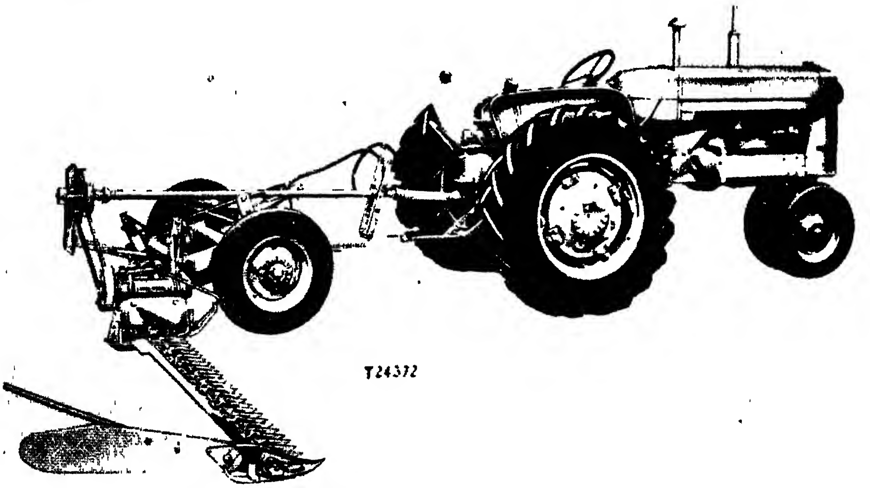


Fig. 16-1. Trailing or pull-type mower. Power is transmitted by V belt from the power take-off shaft to the pitmanless knife drive. (*Allis-Chalmers Mfg. Co.*)

tractor drawbar (Fig. 16-1). The arrangement gives flexibility and allows the cutter bar to follow the contour of the ground. Power may be transmitted by gears, chain, or V belt. The regular adjustment features are provided. The cutter bar is lifted by a hydraulic or mechanical power lift.

Integral Rear-mounted Mowers. This type of tractor mower is direct-connected to the tractor and is mounted on the tractor drawbar (Fig. 16-2). All the weight of the mower is on the tractor. The power is transmitted directly or indirectly by V belt from the power take-off to the pitman shaft; no gears or universal joints are required. An automatic safety release allows the cutter bar to swing back if an obstruction is hit. This safety release is connected to the tractor clutch foot pedal, and as the bar swings back, it automatically disengages the tractor clutch. Provision is made for the adjustment of the alignment, registration, and tilting of the cutter bar. The cutter bar is lifted hydraulically.

Side- or Central-mounted Tractor Mower. This method of mounting is available for tractors that are equipped with widespread front wheels and for tractors with tricycle-arranged wheels (Fig. 16-3). Tractor operators like side-front-mounted mowers because they can watch the cutter bar more easily. The cutter bar is mounted on the right side of the tractor between the front and rear wheels. This arrangement makes it easy to use

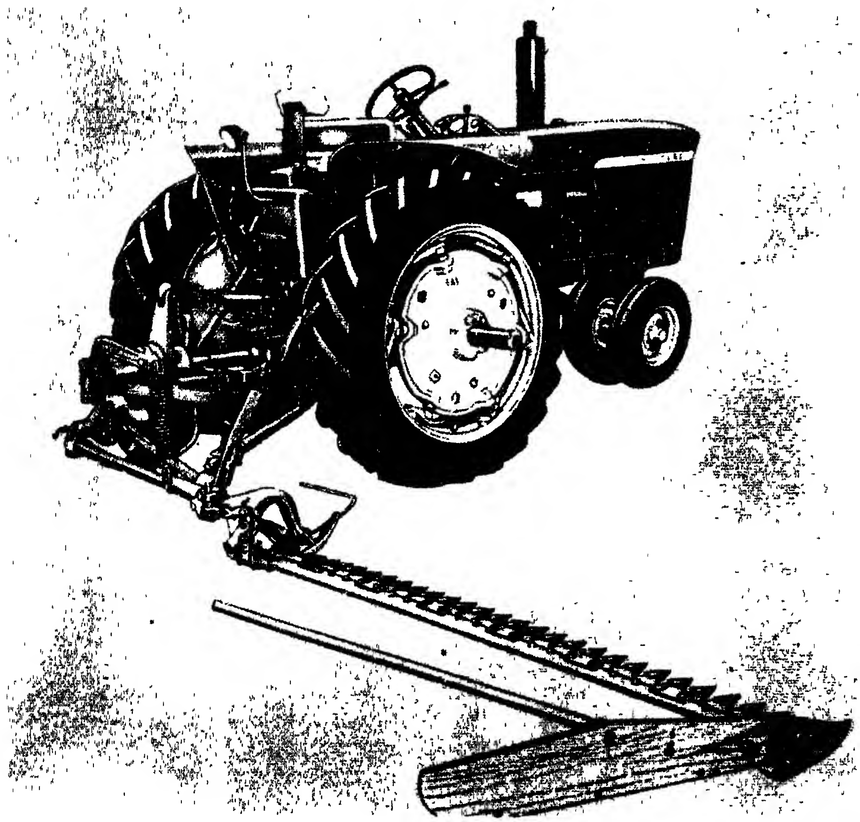


Fig. 16-2. Hitch- or integral-mounted mower. The roller chain drive assembly is enclosed and provides an oil bath lubrication. (*Deere & Co.*)

power lifts. Power is usually taken from the power take-off by V belt and transmitted to the knife through shafting, gears, and pitman. Automatic safety releases and snap or slip clutches are provided. Means of adjusting the alignment, registration, and tilting of the cutter bar are also provided.

Safety Release Clutch. A safety release clutch is essential on tractor mowers to permit the cutter bar to swing back should the cutter bar hit an obstruction while the tractor is moving forward.

Knife Drives. Prior to 1952 all mower knives were driven by a pitman which served as a connecting rod from a counterbalanced wheel to the knife, thus converting rotary motion to a reciprocation motion. The development of the pitmanless counterbalance drive eliminates the need for a pitman. Some counterbalance drives use a single counterbalance

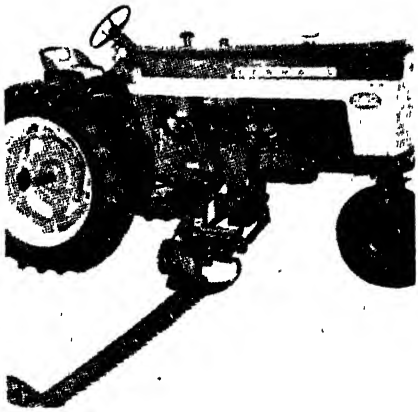


Fig. 16-3. Side- or centrally mounted pitmanless mower. (*International Harvester Company.*)

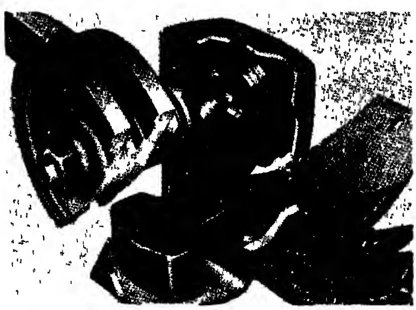


Fig. 16-4. Pitmanless knife drive with single counterbalance. (*International Harvester Company.*)

(Fig. 16-4), while others use twin counterbalance wheels (Fig. 16-5). This type of drive reduces vibration, permits a faster knife speed, and allows the knife to operate in 10 to 15 degrees below horizontal to positions almost vertical (Fig. 16-6).

Cutter Bar and Its Parts. For the knife to do its work, it must have aid from a number of other parts which go to make up the cutting mecha-

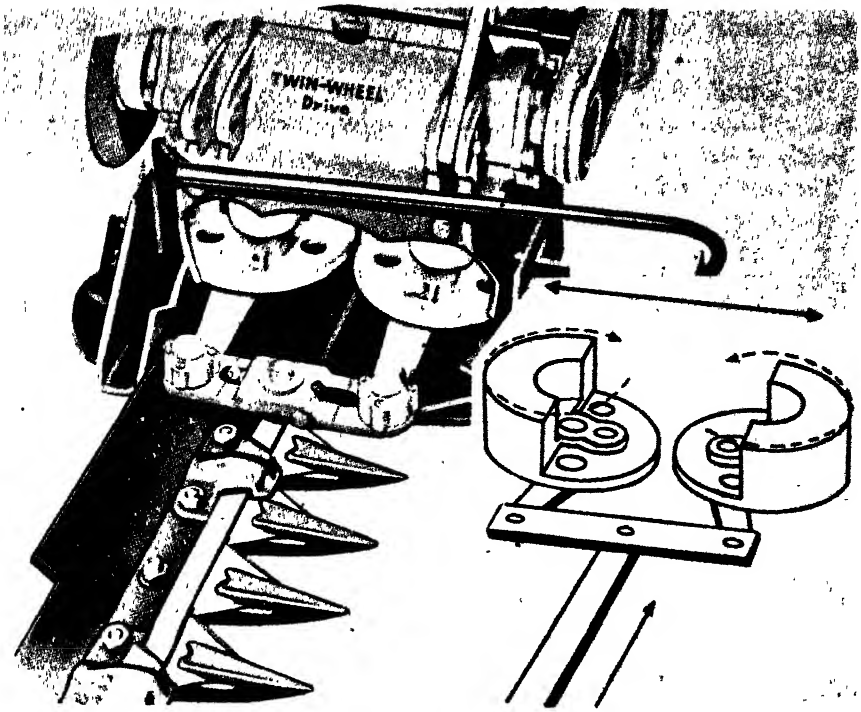


Fig. 16-5. Pitmanless mower knife drive using twin counterbalanced wheels. (*Allis-Chalmers Mfg. Co.*)

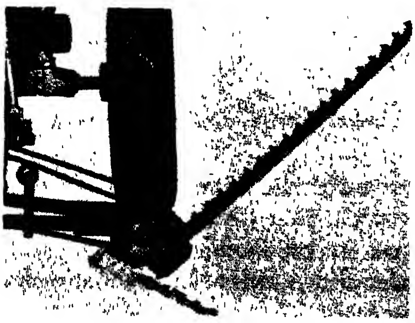


Fig. 16-6. A counterbalance drive permits the knife to be operated in positions below and above the horizontal. (*International Harvester Company.*)

nism (Fig. 16-7). These consist of the cutter bar, inside shoe, outside shoe, guards, ledger plates, wearing plates, knife clips, grass board and stick.

The Cutter Bar. The cutter bar (Fig. 16-8) is made of high-grade steel. All other parts included in the cutting mechanism are connected directly or indirectly to it.

The Inside and the Outside Shoes. A large shoelike runner (Fig. 16-8) supports the inner end of the cutter bar when in operation. A removable

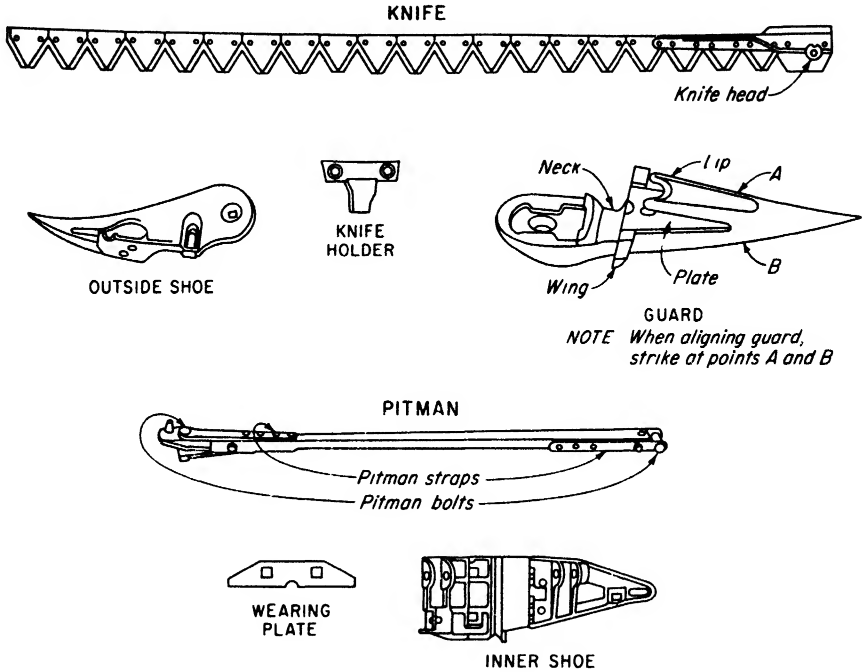


Fig. 16-7. Various parts of a cutter bar with knife and pitman.

sole is placed underneath the shoe and is adjustable to regulate the height of cut. The outside shoe (Fig. 16-8) supports the outer end of the cutter bar. It also has an adjustable sole to regulate the height of cut. The pointed front part of the outer shoe acts as a divider, separating the cut from the standing grass.

The Guards. The guards serve to protect the cutting units (Fig. 16-9). They also provide a place for the ledger plates. They divide the material being cut so that the cutting units can do the best work. If one of the guards gets out of alignment, it should be hammered back in place. Special grain or pea- or bean-vine lifters are often used to facilitate the cutting of fallen material.

Ledger Plates. The ledger plates are riveted to the guard (Fig. 16-9). They form one half of the cutting unit, the knife sections acting as the other half. The edges of the ledger plates are serrated to prevent stems of grass from slipping off the point of the shears. When a ledger plate becomes worn and dull, it should be replaced with a new one. A special

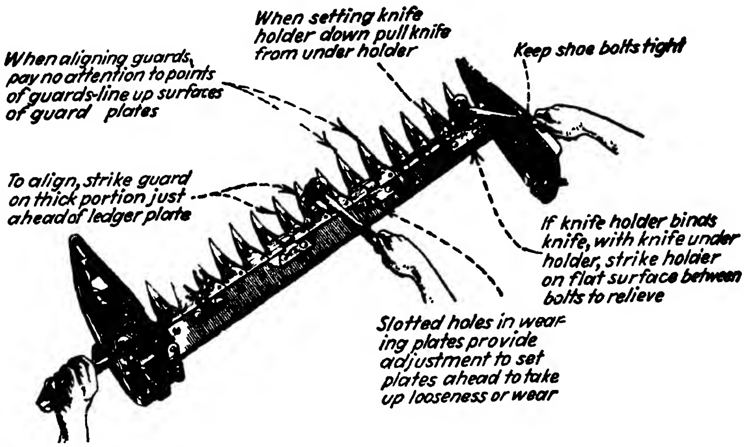


Fig. 16-8. Complete mower cutter bar with instructions for adjustments.

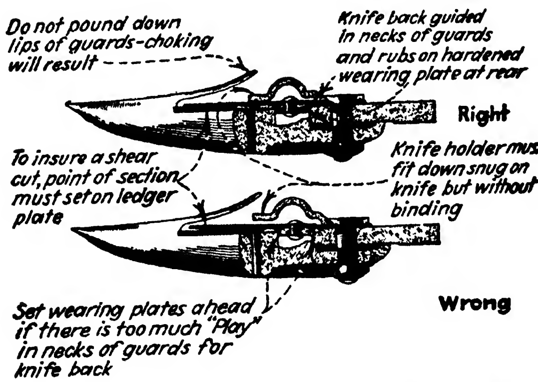


Fig. 16-9. Right and wrong way for mower knife to fit and operate in the guards.

anvil for removing and replacing ledger plates and knife sections is available for repair work from factories making mowers.

Wearing Plates. Wearing plates (Fig. 16-7) are necessary to support the rear side of the knife. When they become worn, the rear side of the knife will drop down, causing the sections to kick up and make poor contact with the ledger plates. Heavy draft and poor cutting will result

from such a condition. The wearing plate under the knife head should not be overlooked when a mower is being repaired.

Knife Clips. Knife clips or holders (Fig. 16-7 and 16-9) are essential to hold the knife sections down close against the ledger plates. If they become worn and allow the knife to play up and down, making poor contact with the ledger plates, they should be hammered down. They are made of either malleable iron or steel.

Grass Board and Stick. These parts are attached to the outer shoe (Fig. 16-1). The board, with a yielding spring connection, angles back and away from the uncut grass. Its purpose is to divide and rake away the cut from the uncut grass to give a clean place for the inside shoe on the next round. For long and tangled material, a *rotary* grass board can be secured that will leave a cleaner swath than the regular type.

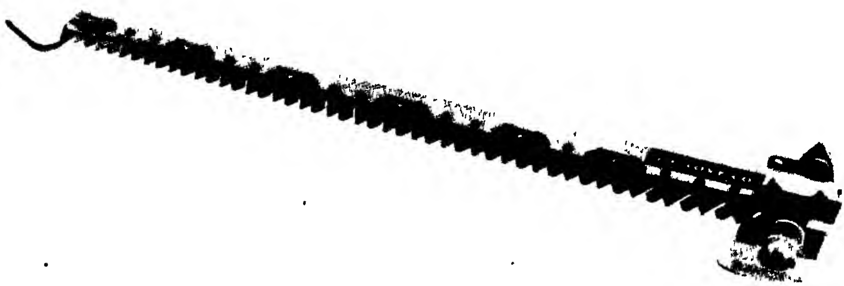


Fig. 16-10. A mower cutter bar equipped with fixed and movable knife blades. (*J. E. Love Co.*)

Figure 16-10 shows a double sickle cutter bar. Knife sections are substituted for the guards and ledger plates. Thus, the sections of the moving knife cut against the fixed section attached to the cutter bar. This type of cutter bar requires that the field be cleared of all obstructions, loose sticks, and rocks.

Alignment of Cutter Bar. The outer end of the bar should be ahead of the inner end 1¼ to 1½ inches on 5-foot cutter bars, 1½ to 1¾ inches for 6-foot cutter bars, and 1¾ to 2 inches for 7-foot cutter bars. This setting is called *lead.* When the mower is in operation, the friction between the cutter bar and the ground causes the bar to swing slightly backward, and this brings the knife in line with the pitman.

Figure 16-11 shows a method of measuring to determine the proper lead for the cutter bar.

Registration. Registration means that, when the wrist pin on the crank wheel pulls or pushes the pitman and knife to the extreme end of the in and out strokes of the knife, the center of the knife sections should be

at the center of the guards for a pitman mower. Failure to register is a very common trouble in mowers and should be looked for often.

Figure 16-12 shows that the knife sections do not quite reach the center of the guards at the end of the knife stroke for a pitmanless mower.

Fig. 16-11. Method of checking lead for mower cutter bar. Note that the outer end of the knife is about 1½ inches ahead of the string which is in line with the pitman.

The results of failing to register are an uneven job of cutting, an uneven load on the entire mower, heavier draft, and, often, clogging of the knife. When an attempt is made to align the cutter bar by lengthening or shortening the drag bar, it may, at the same time, disturb the registration of the knife sections with the guards. To adjust the registration on most

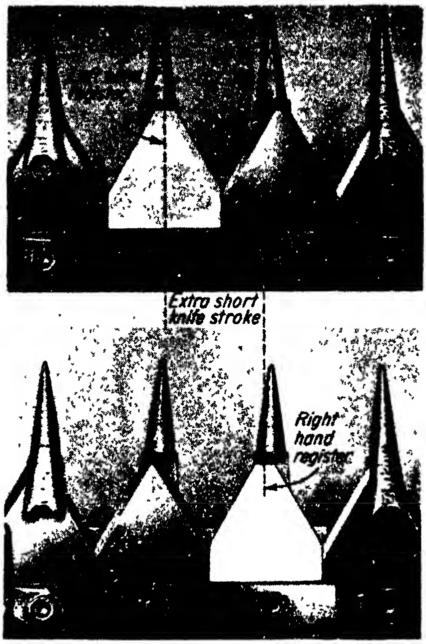


Fig. 16-12. Registration of the knife sections with the guards for a pitmanless mower. Note that the knife sections do not quite reach the center of the guards at the end of the knife stroke. (*International Harvester Company.*)

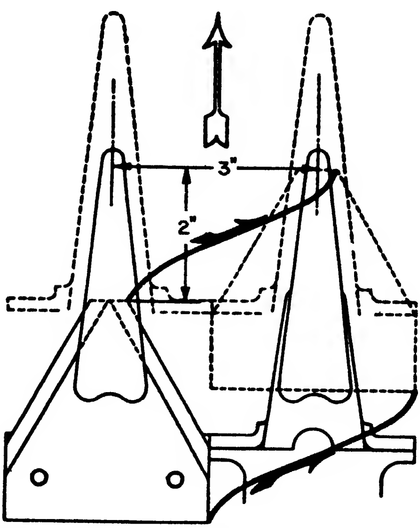


Fig. 16-13. Diagrammatic sketch showing movement of mower knife section in making single stroke. The knife is moved forward 2 inches and sidewise 3 inches with the tractor in low gear. The path of the knife section during the stroke is a curve. (*Allis-Chalmers Mfg. Co.*)

mowers, it is necessary to move the whole cutter-bar assembly in or out to the point where the centers of the knife sections coincide with the centers of the guards at the ends of the strokes. On some mowers, the registration is adjusted by changing the length of the pitman by the addition or removal of shims between the pitman arm and the pitman head socket. As the knife sections move from the center of one guard to the center of another, the movement is forward and sidewise in a curve, as shown in Fig. 16-13.

Kepner[2] states that "the average cutting force during the cutting portion of the stroke may be at least as great as the maximum inertia force of the knife, and should be expected to cause vibration effects of considerable magnitude in a single-knife machine. For a given mower the average cutting force is directly proportional to the feed rate."

The knife on a pitmanless counterbalanced mower can be operated at a higher speed than on the mower with a pitman, as there is less vibration. The knife should be kept as sharp as possible because a dull knife may increase the draft 30 to 35 per cent.

Cutter-bar Attachments. The mowing machine is often required to operate under difficult conditions and to perform various kinds of special work. Attachments are available for the cutter bar to facilitate doing such jobs and are mentioned briefly.

Cutter-bar Power Lift. Some tractor-mounted mowers are provided with hydraulic remote-control cylinders to lift the cutter bar.

Grain, Pea, and Bean Lifters. These lifters consist of guards attached over the regular guards, which project quite a distance in front so that pea and bean vines can be lifted, allowing the cutter bar to slide underneath and cut off the stems below the heads.

Weed Attachment. This attachment consists of a wheel placed at the outer end of the cutter bar to carry it some 6 to 12 inches off the ground so that the weeds can be cut without undue strain upon the mower parts.

Weed and Brush Bars. These bars are constructed with stub guards instead of the long sharp-pointed guards used for cutting grass. Extra-heavy knives are also used with them.

Windrowing Attachment. The windrowing attachment consists of a number of bars attached to the cutter bar, curved upward at the rear end. The bars are about 3 feet in length at the outer end and gradually increase in length toward the inner end, where they are some 8 feet long. The hay is allowed to slide to the side into a windrow. Some of these attachments can be folded to allow bunching. The windrow attachment is especially adapted for harvesting flax, clover, alfalfa, peas, and other crops.

[2] Robert A. Kepner, Analysis of the Cutting Action of a Mower, *Agr. Engin.*, 33(11):693, 1952.

Bermuda Grass Cutter Bar. Another special type of cutter bar being made has twice as many guards as the regular type. These guards are narrow, with ledger plates on each guard, and are so placed that the knife, in making an in or an out stroke, passes through two guards instead of one. It is claimed that this arrangement is effective in cutting Bermuda grass, which becomes very closely matted together.

Lespedeza Bar. The lespedeza cutter bar is equipped with special narrow guards, a seed screen, and a pan to receive the seed.

HAY CONDITIONERS

The conditioning of hay by means of crushing, crimping or flailing is becoming increasingly popular with many haymakers. Boyd[3] gives the following advantages of conditioning hay:

1. Speeds field curing. Conditioning can reduce drying time by about 30 per cent.
2. Reduces weather damage.
3. Field losses due to shattering are reduced as curing time and the amount of turning and tedding are reduced.
4. Conserves color and feed value through shorter exposure and less shattering.

There are three general types of hay conditioners: the smooth roll, the corrugated roll or crimper, and the flail-type forage harvester.

The smooth-roll type may use two rubber rolls or a combination of a rubber roll and a steel roll. The smooth rolls give a continuous crushing action to the hay, leaving no part not crushed. Most rubber rolls have spiral grooves to aid in picking up the hay and feeding it between the rolls (Fig. 16-14).

The corrugated-roll- or crimper-type conditioner may be equipped with two malleable-iron rolls, with tapered flutes that mesh together similar to gear teeth, or with slatted bar rolls. Some models use a fluted or bar roll that presses against a smooth rubber roll. As the hay passes between the rolls, it is bent, crimped, and cracked at intervals but not completely crushed.

The flail-type conditioner is really a hay harvester, but when it is used as a hay conditioner, the shear bar is removed to reduce the cutting action. The hay is partially chopped by the swinging hammers or knives.

Figure 16-15 shows a self-propelled windrower that is equipped with hay-conditioning rolls. It is claimed that 80 acres of hay can be cut, conditioned, and windrowed in a day.

[3] M. M. Boyd, Hay Conditioning Methods Compared, *Agr. Engin.*, 40(11):664–667, 1959.

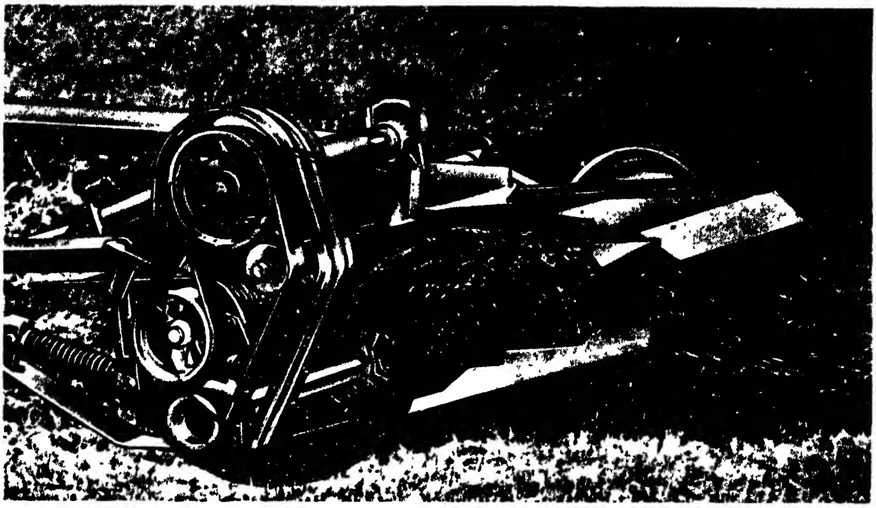


Fig. 16-14. Cutaway view of hay crusher showing section of rubber crushing rolls, the windrowing action, and the V-belt drive for the rolls. (*International Harvester Company.*)

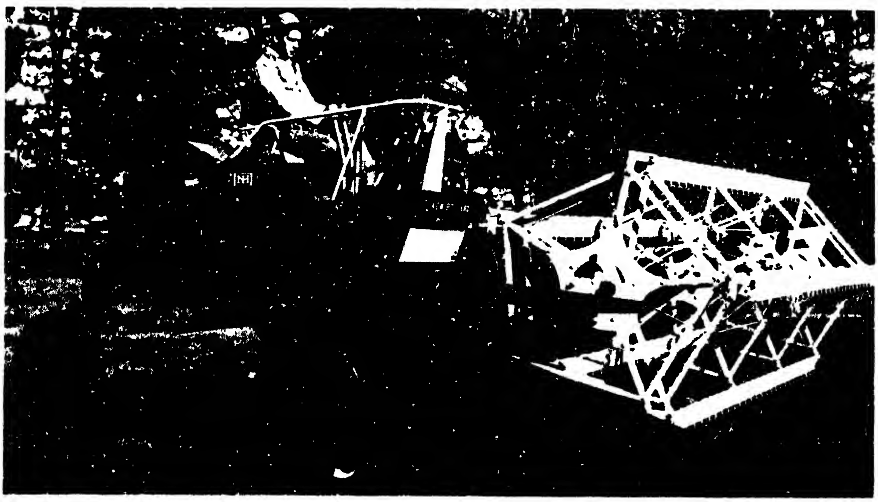


Fig. 16-15. A self-propelled hay windrower. (*New Holland Machine Co.*)

Tests conducted by Person[4] showed that alfalfa hay dried faster when crushed with smooth rollers than when crimped with corrugated rollers (Fig. 16-16).

[4] Nat. K. Person, Jr., Comparative Methods of Curing Forage Crops, Paper presented to the Southwestern Section of the American Society of Agricultural Engineers, April, 1962.

To obtain a quick rate of drying, hay should be conditioned within 15 or 20 minutes after it is cut. Figure 16-17 shows a hay conditioner being used behind and in combination with a trailing-type mower. The propeller shaft for driving the mower is extended to drive the hay conditioner simultaneously. Figure 16-17 shows the mower to the side of the tractor and the hay conditioner behind the tractor. Hay conditioners may be equipped with windrow attachments (Fig. 16-14).

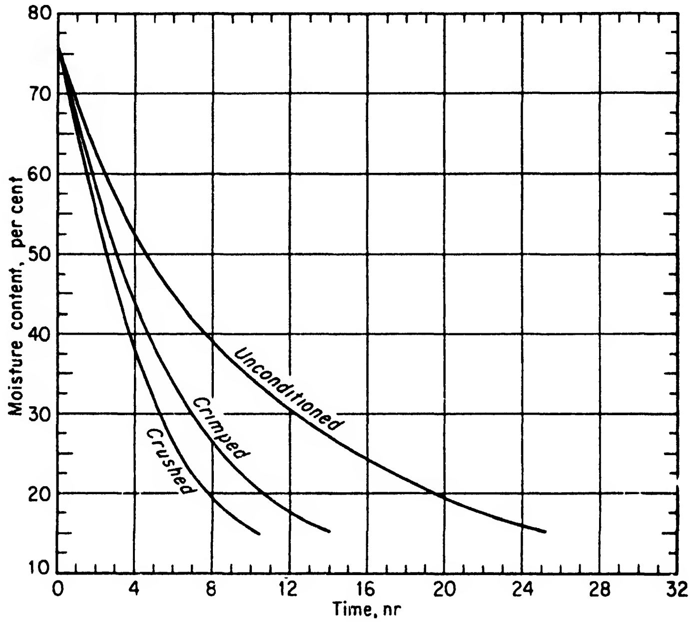


Fig. 16-16. Comparison of moisture content at various hours during the drying period for different methods of conditioning alfalfa. (*Texas Agricultural Experiment Station.*)

Machines are available that cut, windrow, and crush the hay in one operation.

HAY RAKES

Hay rakes can be classified as *dump, side-delivery,* and *sweep.*

Dump Rakes. The dump or sulky rake was developed as a horse-drawn rake. This type of rake consists of long curved teeth mounted 3 or 4 inches apart on a bar axle 10 to 14 feet in length. The axle is supported by two wheels. The teeth can be raised by engaging pawls in the hubs of the wheels.

Side-delivery Rakes. The use of hay loaders and pick-up hay balers created a demand for a hay rake that would make a loose, fluffy, continuous windrow. Then, too, many haymakers rake the hay into windrows directly after it is cut. Such windrows must necessarily be loose to allow the hay to cure. The side-delivery rake was developed to take care of this demand. It is also used to windrow peanuts.

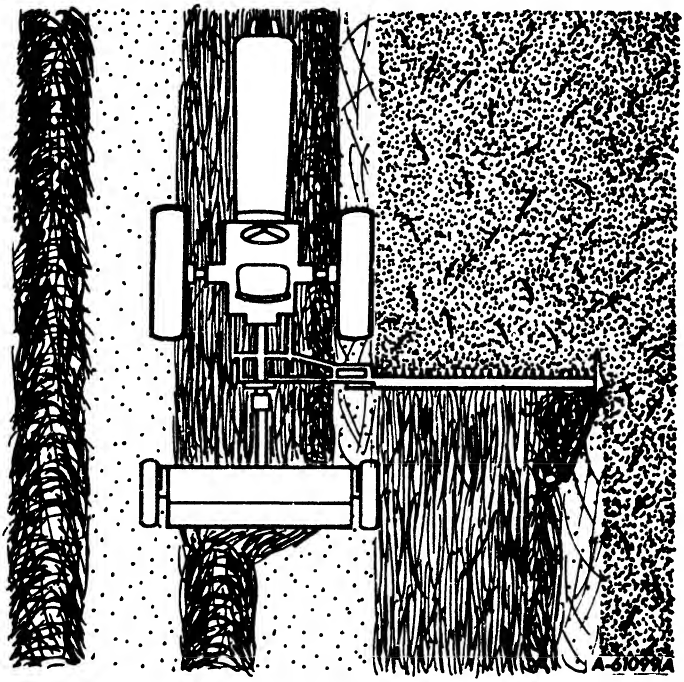


Fig. 16-17. Drawing showing an overhead view of a side-mounted mower with hay conditioner pulled behind the tractor.

Side-delivery hay rakes can be classified according to the types of reel construction, which are *cylindrical-reel*, *parallel-bar* or *side-stroke*, and *finger-wheel*.

The Cylindrical-reel. The cylindrical-reel type (Fig. 16-18) is equipped with a four- or six-bar cylindrical-type reel. The reel is suspended under a heavy angle-iron frame at an angle of about 45 degrees with the direction of travel. As the rake is drawn forward, the reel is revolved so that the spring teeth on the rake bars move forward along the ground, thus raking the hay as the reel moves. The angle of the reel causes the hay to move along the front of the reel toward the trailing end and roll off in a loose roll. The direction of travel is the same as that of the mower, and

the heads of the hay are rolled to the inside of the windrow, while the larger and juicier stems are left on or near the surface of the roll.

The reel bars are attached to three spiders. The rake teeth are curved forward near the end to aid in picking up the hay. Most teeth are made of spring steel and have a coiled section next to the reel bar. One make uses a rubber ball joint for flexibility.

While in contact with the hay, the teeth are held at an angle, with the points leading. This gives a pushing with a slight lifting action to the hay. The tooth bar is turned slightly to maintain the tooth angle. This action may be termed a feathering action (Fig. 16-18). The drive mechanism to hold and feather the teeth may be by an eccentric spider, cam track, or planetary gears.

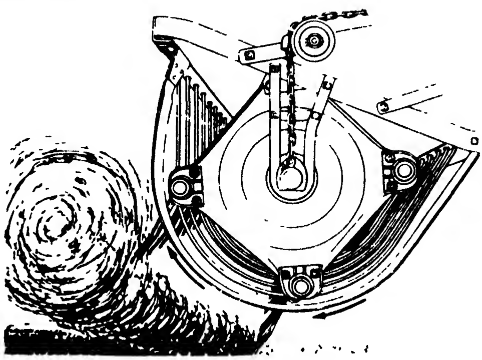


Fig. 16-18. Showing the action and angle of the cylindrical-reel hay rake teeth

The hay is prevented from following or hanging on the teeth by stripper bars (Fig. 16-18). As the stripper bars partially surround the reel underneath, it is termed a *basket*. The reel and basket are suspended under a light- or heavy-duty frame.

Cylindrical-reel side-delivery hay rakes are available in three general types: the ground-driven trailing, the semimounted ground-driven, and the tractor-mounted power-take-off-driven.

The Parallel-bar or Side-stroke Hay Rake. This type of rake may have from four to six reel bars attached to two parallel plates or spiders at each end of the reel (Fig. 16-19). The right front plate faces to the rear, while the left rear plate faces to the front. The plates are set at right angles to the direction of travel. The plates have short stub shafts fitted with sealed roller bearings for the reel bars. As the reel revolves, each bar rotates within the bearing mounts to keep the teeth in a vertical position at all times. When a bar approaches its lowest position, teeth come in contact with the hay, raking for a short distance, to be followed by the next bar. The angle of the teeth can be changed only by tilting

the entire reel. The hay is moved to the side by parallel strokes of the reel bars with less agitation than it is moved by the cylindrical reel. Figure 16-20 shows the action of the two types of rakes.

The width of swath raked by the parallel-bar rakes ranges from 7 to 8½ feet.

The Finger-wheel. The finger-wheel reel hay rake shown in Fig. 16-21 consists of five individually floating wheels set in a half-squadron arrange-

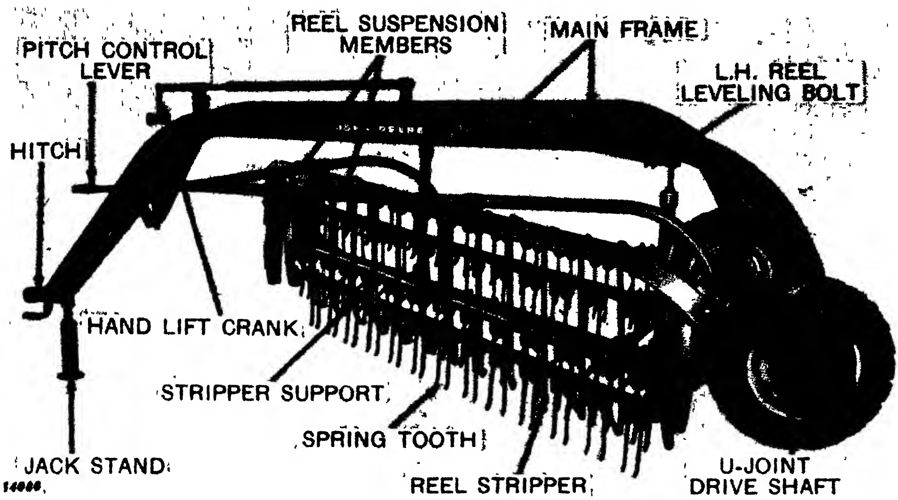


Fig. 16-19. Semimounted parallel-bar hay rake showing reel drive from left rear wheel. (*Deere & Co.*)

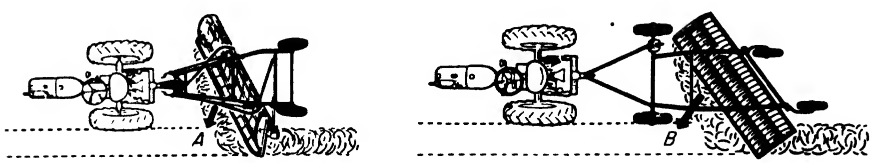


Fig. 16-20. Drawings showing the action of the parallel-bar rake at *left* and the cylindrical-reel rake at *right*.

ment. Fingers with a coil base are attached to the rim or periphery of the wheel. The fingers contact the ground lightly, and as the rake is drawn forward, the diagonally set wheels revolve and produce a drag-stroke action which moves the hay forward and to the side in a line about parallel to the axle of the wheel.

The wheels are attached to a crank arm and are partially supported by a tension spring so that they will follow the contour of the ground without excessive pressure on the ground. The wheels will "snake" over

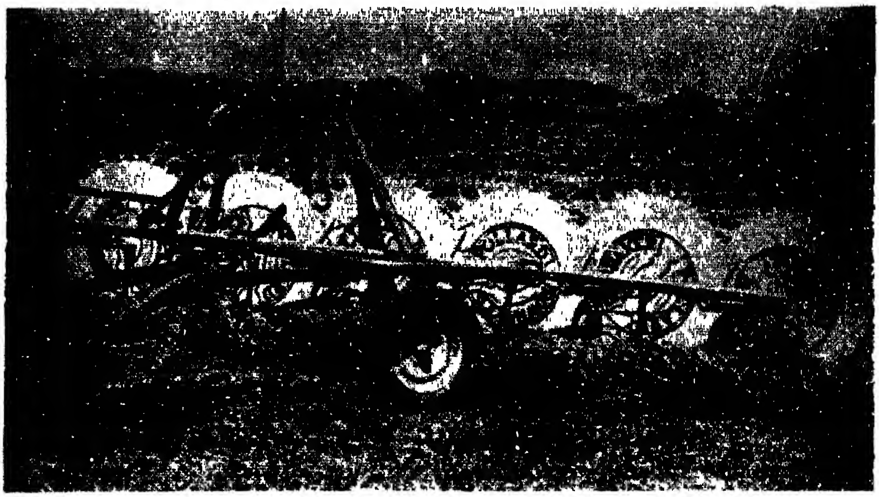


Fig. 16-21. Side view of finger-wheel hay rake showing how the hay is rolled to the side. The spokes of the wheel are covered to prevent hay entanglement. (*Pollard Mfg. Co.*)

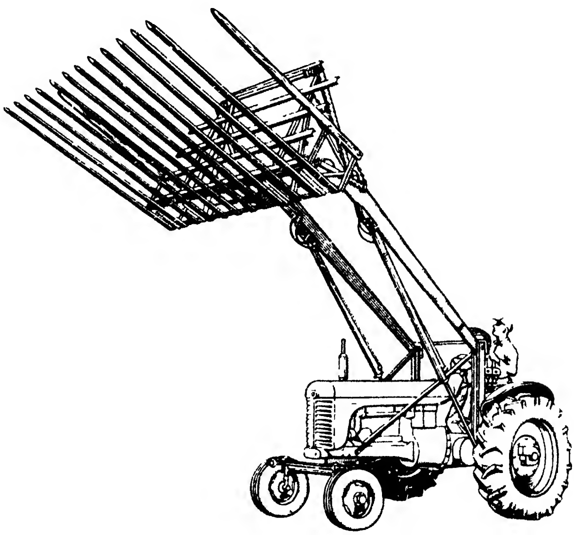


Fig. 16-22 Tractor-mounted sweep rake that can also be used as a stacker.

a terrace or irrigation ditch, raking the hay without damage to the rake.

Sweep Rakes. A typical tractor-mounted sweep rake is shown in Fig. 16-22. The raising and lowering of the teeth are operated by power from the tractor. The sweep rake is sometimes called a *buck* or *bull* rake. It is useful in collecting hay from the windrow and transporting it short distances to a stationary baler or to a stack.

HAY LOADERS

To facilitate the rapid handling of hay and to eliminate a great deal of manual labor, the hay loader was developed for taking the hay either out of the windrow or directly out of the swath and elevating it up onto the trailer wagon. The hay is picked up by a revolving pickup cylinder and delivered onto a sloping sheet-metal deck. The hay is moved up the deck either by toothed oscillating bars or by a slatted conveyor belt.

HAY STACKERS

In some sections, hay is stacked in the field rather than stored in the barn. Many types of stackers are built, both commercially and locally.

Where medium-sized stacks are put up, sweep-rake type stackers attached to tractors can be used. A trip arrangement permits the operator to drop the load of hay on the stack.

HAY BALERS

When hay is being grown for commercial purposes and has to be shipped, it should always be baled so that as much as possible can be put into the average railway car or loaded onto a truck. Many hay growers prefer to bale their hay before storing it in the barn in order to conserve space.

Pickup Automatic Self-tying Balers Making Rectangular Bales. This type of baler is an automatic-pickup, self-feeding, and self-tying machine which requires only one man, who drives the tractor (Fig. 16-23). Some makes are operated by a gasoline engine of about 14 horsepower, while others are operated by the power take-off of the tractor. A self-propelled baler is shown in Fig. 16-23. The size of the rectangular bale varies from 14 by 18 to 16 by 18 inches and from 32 to 42 inches in length. The weight of the bales produced will vary from 40 to 90 pounds, depending upon the kind of hay being baled and its moisture content. The average bale will weigh 60 to 75 pounds. Some makes of balers use a 15-gage wire supplied in rolls, while others use heavy, strong twine for tying the bales. It is estimated[5] that about 68 per cent of the hay crop produced in the United States in 1952 was baled. Approximately 25 per cent was stored as loose, unchopped hay.

The pickup and feeder for the hay baler may be either on the right or left side of the machine according to the designer's preference. There are at least four methods of feeding the hay into the press chamber: auger and packer fingers, spring teeth and feeder arms, auger and feeder head, and carrier-roller feed.

Figure 16-24 shows a pickup cylinder that delivers the hay direct to a

[5] *U.S. Dept. Agr. BAE Preliminary Rpt.*, 1952.

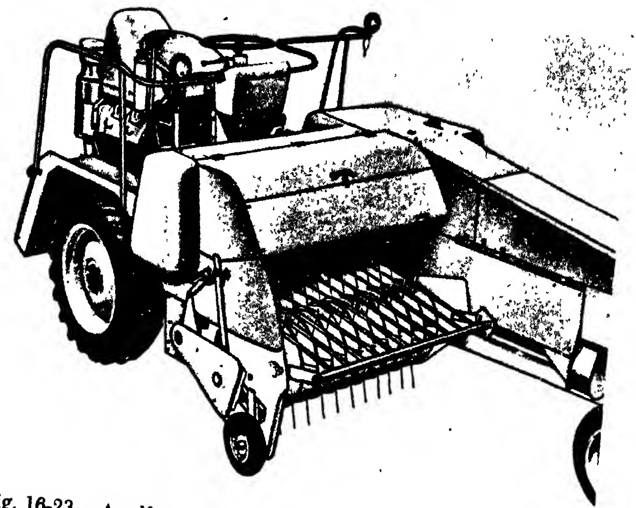


Fig. 16-23. A self-propelled hay baler. (*New Holland Machine Co.*)

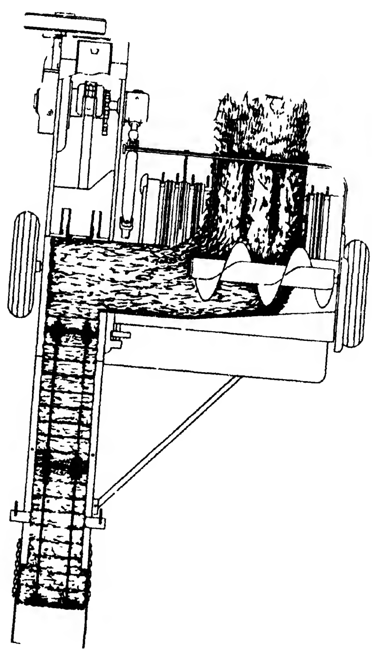


Fig. 16-24. Overhead view of auger to feed hay into the bale chamber. (*International Harvester Company.*)

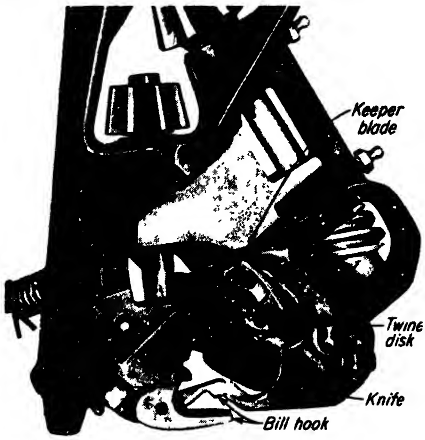


Fig. 16-25. Twine knotter head for an automatic hay baler. (*International Harvester Company.*)

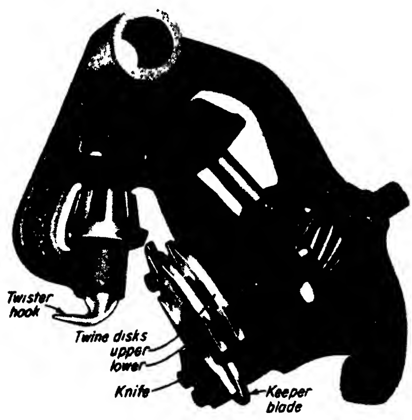


Fig. 16-26. Wire twister for an automatic hay baler. (*International Harvester Company.*)

floating-feed cross auger from which it passes to packer fingers, which feed it into the bale chamber.

Figure 16-23 shows a one-man self-propelled pickup automatic self-tying hay baler.

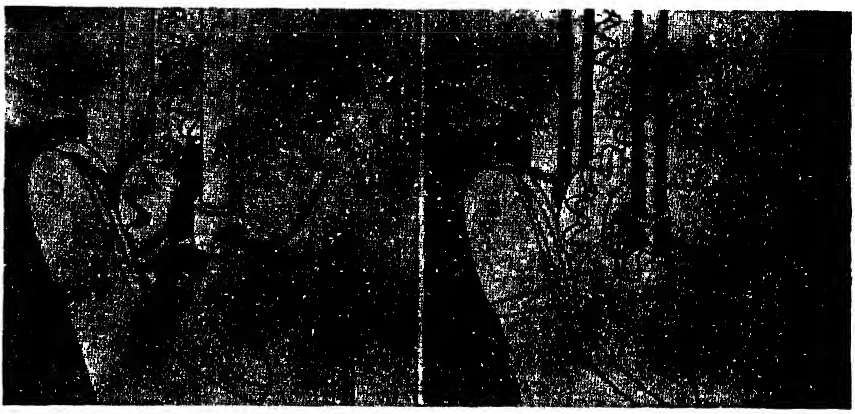
Tying Mechanisms. The development of a pickup feeding mechanism, of tying mechanisms for heavy twine, and of twisting or tying mechanisms

for wire, all of which operate automatically, makes the modern hay baler a truly automatic machine.

The twine knotters are similar to the twine knotters used on grain binders (Fig. 16-25). It is necessary, however, to have two needles and two knotters to tie the two twine bands simultaneously around the bale.

(1) Needle brings lower wire around the end of the bale and . . . .

(2) . . . places it under the wire in the twister pinion.



(3) Now the twister pinion revolves four times, twisting both wires securely. This makes a twist about 3 inches long.

(4) Kinker shaft (behind pinion) and cutoff shaft (near side) turn to the outside. The kinker shaft kinks the knot on the bale being tied . . . the cutoff shaft cuts the twist and kinks the knot on the wire for the next bale. Note that the twist is cut only once . . . there are no wire clippings.

Fig. 16-27. Steps in making a kinked wire twist for

The wire-twisting mechanism shown in Fig. 16-26 is similar to a regular binder twine knotter. The wire twisting mechanism shown in Fig. 16-27 is termed a *kink twist.*

Manufacturers provide trouble-shooting charts for their tying mechanisms. These charts should be carefully studied to determine the cause of tying troubles and their remedies.

Pickup Automatic Baler Making Round Bales. This type of hay baler is termed a *Roto-Baler* (Fig. 16-28). The hay is raked into large, double windrows so there will be an ample volume of hay the full width of the pickup conveyor. The swath of hay is picked up by the pickup conveyor and fed into bale-rolling mechanism shown in Fig. 16-28.

A *bale slide* can be attached to most pickup balers so that the bales of hay can be loaded directly on a trailer that is attached to the rear of the baler.

Bale Throwers. The mechanism shown in Fig. 16-29 is an automatic bale ejector that throws the tied bale of hay into a trailing wagon.

Bale Loaders. Several types of bale loaders are now available whereby the bales of hay are automatically picked off the ground and elevated by an endless carrier chain to a height where a man on a trailer wagon or truck can take the bales and stack them on the truck (Fig. 16-30).

(5) Shafts return to neutral position, and needles move downward, drawing wire into position for the next bale. As the bale expands when released from compression, the end of the knot is drawn into the bale, and the double-kinked twist is locked into a nonslip S-curve.

(6) Enlarged view of kinked twist.

one type of bale-tying mechanism. (*Deere & Co.*)

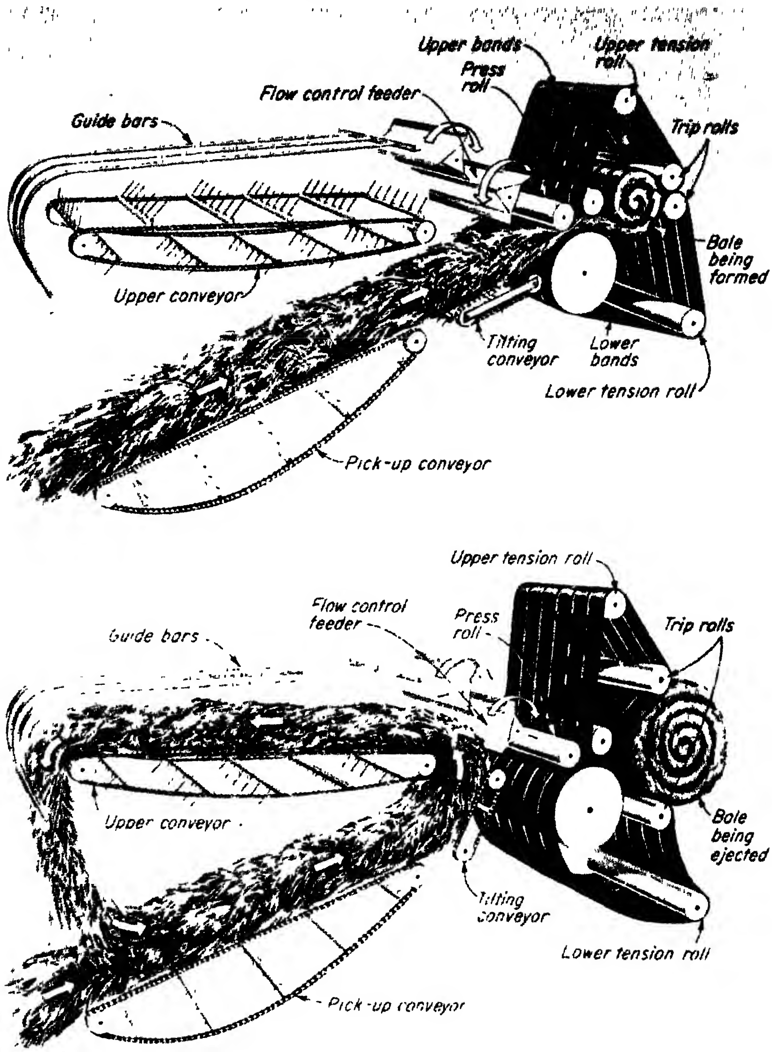


Fig. 16-28. Method of making round bales of hay: *top,* feeding hay into baling chamber where it is compressed between belts; *bottom,* showing how the hay is deflected over the upper conveyor of the feeder while the completed bale is being wrapped with twine and ejected. This permits a nonstop operation. (*Allis-Chalmers Mfg. Co.*)

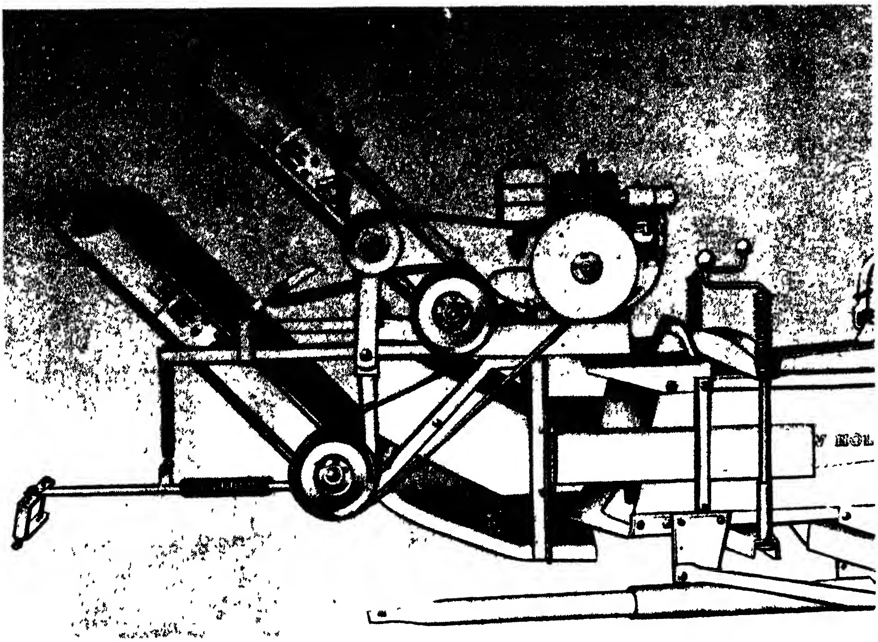


Fig. 16-29. Bale thrower which uses two fast-moving belts to eject and throw the bales into a trailer hitched to the rear of the baler. (*New Holland Machine Co.*)

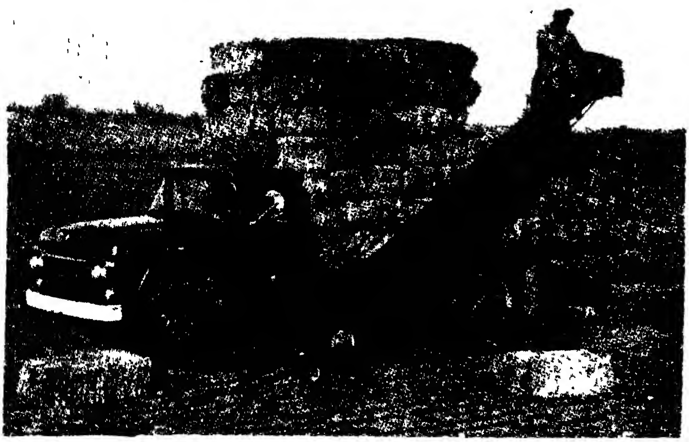


Fig. 16-30. Field pickup bale loader that can be adjusted for height. (*Graves Mfg. Co.*)

Portable elevators for loading bales of hay into the barn are shown in Chap. 24.

FARM HAY DRYERS

The artificial drying of hay with and without heated air is discussed in Chap. 23.

FIELD HAY WAFERING EQUIPMENT

In the late thirties and early forties commercial and cooperative plants were developed for the drying of alfalfa hay for the production of alfalfa meal to be used especially in poultry feeds. In the late forties there was considerable interest in the development of commercial plants for producing hay in pellets. The investment required for housing, equipment, and operation for each of the above systems was beyond the average hay producer.

The practice of lot-feeding livestock, particularly cattle, has increased and created a need for hay in a form that requires a minimum storage space and can be easily handled by mechanical equipment. This need has brought about the development of field equipment that will process loose hay into compact 1- by 2- or 2- by 2-inch cubes or 3-inch-square wafers. The wafers must have sufficient cohesive qualities to withstand crumbling and breakage in handling.

The hay is prepared for wafering by being placed in windrows with a flail-type hay harvester. It is cured to about normal moisture content. The field hay wafer machine has a flail-type pickup which delivers the hay to the hopper from which it is fed into the compressing dies. Hydraulic pressure may vary from 100 to 1,000 pounds per square inch. The bulk density of the wafers is about 25 pounds per cubic foot. The capacity ranges from 5 to 6 tons per hour. A 125-horsepower engine is required to operate the machine.

The field hay wafering machine is at this time still in the experimental and development stage.

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QUESTIONS AND PROBLEMS

1. Explain the different ways in which a tractor mower can be mounted, and give the advantages of each.
2. Explain what is meant by register in a mower knife. Explain how register is determined and adjusted.
3. Explain what is meant by alignment of a mower cutter bar. How is it determined and adjusted?
4. What are the advantages of a pitmanless mower?
5. What are the advantages for conditioning hay?
6. Describe three types of hay conditioners.
7. Explain the differences in action of the cylindrical-reel, parallel-bar, and the finger-wheel types of hay rakes.
8. Explain how round bales of hay are formed.
9. What are the advantages of a bale thrower?
10. What is meant by hay wafering?

FORAGE HARVESTING EQUIPMENT

17

Beef and dairy cattle and other types of livestock will remain in better condition during the winter months if they receive a succulent feed. As there are no green pastures in the winter, such feed must be grown, harvested, processed, and preserved in a silo so that it will be available when needed. In the Northern states corn is the principal silage crop, while in the Southwest sorghum is used more than corn. The use of grasses for silage is growing in popularity. Some field-cured hay is chopped and stored as chopped hay in the barn.

The former method of putting up silage was to cut and bundle the crop with a row binder and then haul the bundles of stalks to the silo, where they were chopped up and blown in for storage. The silo may be either an upright cylinder 20 to 40 feet in height or a long trench dug in the ground. The trench may be 8 to 12 feet wide at the top and 30 to 60 feet in length, the size depending upon the tonnage of the silage to be put up. Self-feeding trench silos are becoming popular. A few pit silos may be found.

The various methods and operations required in handling chopped hay and forage crops are shown in the following chart:

ROW CROPS

Field operations	*Barn or silo operations*
Cut and bind, load manually, transport	Unload and feed manually, chop and blow
Cut and chop, transport	Unload, blow

BROADCAST CROPS AND GRASSES

Field operations	*Barn or silo operations*
Cut, cure, windrow, chop, transport	Unload, blow
Cut, windrow, chop, transport	Unload, blow
Cut and chop, transport	Unload, blow

ROW–CROP FORAGE HARVESTING EQUIPMENT

As shown in the above chart, there are two methods of harvesting and chopping green row crops to fill silos.

Row-binder and Ensilage-cutter Method. The first and oldest method requires a row binder to cut and bind the crop into bundles. Horse-drawn row binders have been supplanted largely by the tractor-drawn power take-off row binder. Usually the bundles of corn or sorghum were dropped on the ground, then manually loaded on wagons, trailers, or trucks and transported to the silo. Some binders were provided with mechanical elevator-loaders. At the silo the bundles were thrown manually from the load onto the carrier apron of a stationary *silage cutter*, which is also called an *ensilage cutter* or *silo filler*. Ensilage cutters consist of a carrier feed table, feed rolls, a cutting head, and a fan to blow the cut material into the silo. The cutting head may consist of either a cylinder of knives or knives attached to a flywheel. The flywheel type also has the fan blades attached to the flywheel. The cylinder types require a blower fan to operate in conjunction with the cutterhead.

Field-harvester and Blower Method. The second method of harvesting and chopping green row crops consists of a combination plant-cutting unit and a chopping unit. The complete machine is called a *field forage harvester* (Fig. 17-1). The field forage harvester performs the functions of both the row binder and the silage cutter, as it severs the standing stalks from the ground and chops them into silage in one continuous operation in the field. It does, however, require a blower at the silo.

There are at least ten advantages of the field forage harvester. They are as follows:

1. Eliminates the drudgery of lifting and loading 10 to 15 tons of heavy green bundles of corn per acre
2. Provides ensilage at lower cost
3. Provides more tons of feed per silo
4. Permits filling the silo when the crop is at the right stage
5. Makes ensilage with greater feeding value
6. Provides more uniformity of feeding value from any part of the silo
7. Provides a more uniform, solid pack without air pockets, thus preventing molds
8. Causes no wilting of leaves or loss of previous moisture
9. Leaves no mud or contaminating soil bacteria on butts

10. Avoids soggy material which often occurs when the silo is filled too early with green, immature corn

TYPES OF FIELD FORAGE HARVESTERS

Field forage harvesters can be divided into two general types according to the method or mechanism used to cut the growing crop. The most versatile type uses interchangeable units whereby windrowed hay, row crops, or broadcast crops can be cut and fed into a chopping unit. It is

Fig. 17-1. Two-row trailing power-take-off-driven field forage harvester. (*Gehl Bros. Mfg. Co.*)

called a *field chopper*. The other type uses free-swinging chains, hammers, or knives attached to a 6- or 8-foot horizontal rotor. This is commonly called a *flail harvester*.

Field Chopper-Harvesters. Field forage chopper-harvesters are available in tractor-drawn and self-propelled types. Some tractor-drawn types are driven by the power take-off of the tractor, while others are driven by an auxiliary engine mounted on the chopper. The offset hitch permits the chopper to trail to the right of the tractor so the tractor does not run on or over crop rows, swath, or windrow (Fig. 17-1).

Several companies provide interchangeable harvesting units for the chopper-blower section (Fig. 17-2).

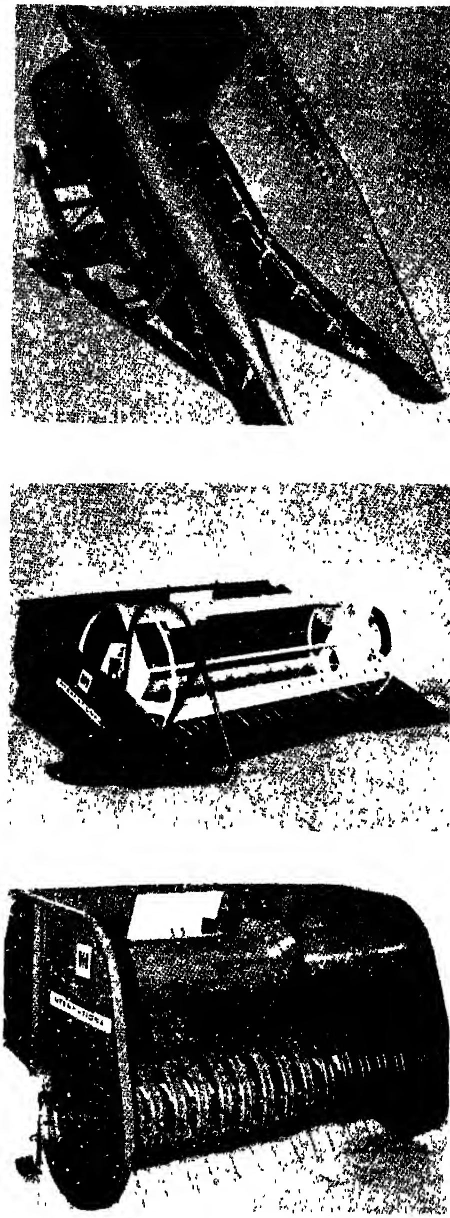

Fig. 17-2. Interchangeable attachments for field forage chopper-harvester. (*International Harvester Company.*)

The row-crop attachment is suitable for harvesting row crops, such as corn and sorghum. It is equipped with two stationary side knives across which a single sickle section oscillates to sever the plants. The plants are moved back by gathering chains and are power fed into the chopping unit.

The cutter bar consists of a regular mower-like cutter bar, a reel to throw the crop back onto an apron which conveys the material back to an auger, which in turn conveys the material to one side where it is fed into the chopping unit.

The pickup attachment has revolving fingers that lift wilted hay from the swath or windrow and move the material back to an auger which in turn conveys the material to the chopper throat.

Figure 17-3 shows two types of cutterheads used on field chopper-harvesters. Both types may be fitted with four or six knives. In the flywheel-type cutterhead, the knives for cutting and the impeller paddles for throwing and blowing are mounted on the wheel separately. The cylinder-type cutterhead usually has the knives designed both to cut and blow (Fig. 17-3). Some cylinder cutterheads require a separate impeller blower. Each type of cutterhead has certain advantages and disadvantages. The cylinder type may have built-in sharpeners, but the knives must be removed from the flywheel for sharpening.

The length of cut or the length of the cut pieces can be varied from about ½ to 2 inches when the stalks are fed straight into the cutting knives. The change in the length is made either by changing the number of knives on the cutterhead or by changing the speed of the feed mechanism. It is essential for efficient operation that the knives and shear plate be kept sharp and the recommended clearance between them maintained. These mechanical factors and the physical condition of the material being chopped will affect the total energy requirements and the horsepower requirements.[1]

The capacity of a field forage chopper-harvester is affected by:

1. The area of the throat opening
2. The speed and rate of feeding
3. The density of the material

The rate of feeding and density are in turn influenced by yield of the crop.

The Field Harvester Blower Spout. A spout or delivery chute is necessary to conduct or convey the chopped material from the blower fan to the wagon or truck (Fig. 17-4). The blower outlet pipe for most choppers is

[1] *Amer. Soc. Agr. Engin. Yearbook*, pp. 124–125, 1963.

F. Z. Blevins and H. J. Hansen, Analysis of Forage Harvester Design, *Agr. Engin.*, 37(1):21–26, 1956.

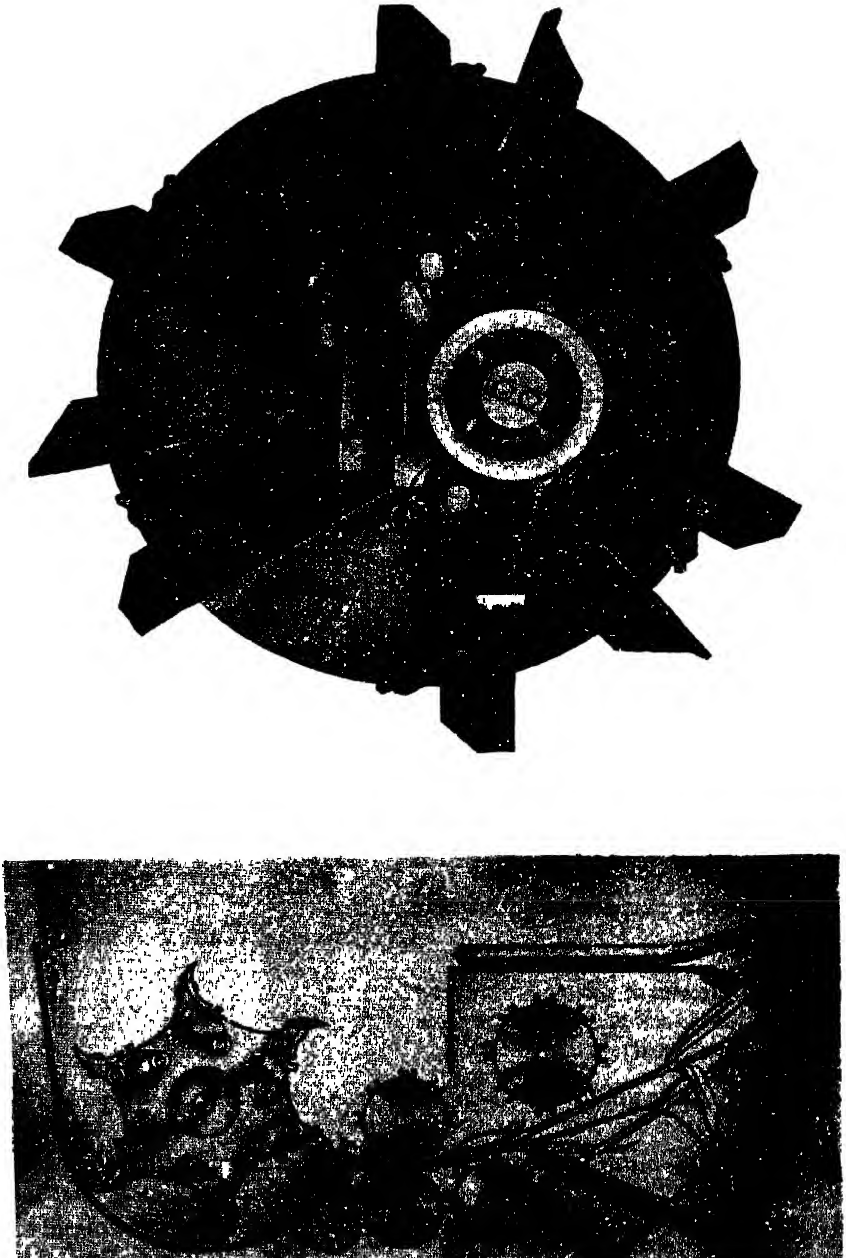

Fig. 17-3. Two types of cutterheads for field forage harvesters: ***top***, **flywheel-type cutterhead;** ***bottom***, cylinder-type cutterhead. (*International Harvester Company, New Holland Machine Co.*)

round, except for the flail harvester, which has a trapezoidal duct over the flails. Extension sections are provided where additional height is required. The blower discharge pipe is usually about 8 inches in diameter. The rectangular delivery spout or chute has a round base to fit the blower discharge. The spout can be set for either side or rear delivery.

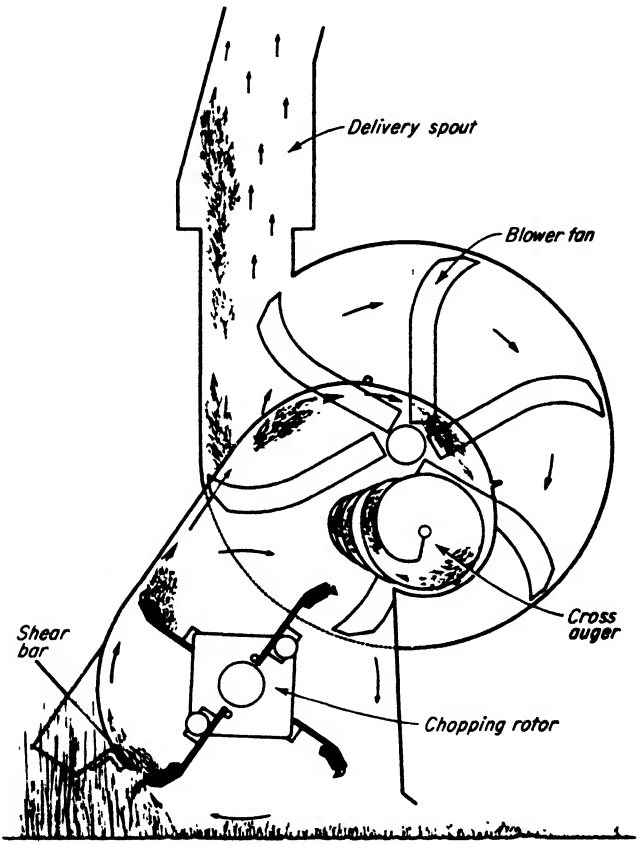

Fig. 17-4. Showing the action of flail knives cutting forage against shearbar. The knives throw the cut material onto a cross auger which feeds the material into a fan. (*Gehl Bros. Mfg. Co.*)

It is about 6 or 8 feet in length and has a gradual curve. The bottom part of the spout is usually open.

The most important part of the spout is the swivel deflector attached to the top end. The lip can be controlled by the tractor operator by means of ropes so the material can be directed to any part of the wagon box.

Forage Wagons and Boxes. A typical forage trailer and self-unloading box is shown in Fig. 17-5. Most boxes are provided with a power-driven slat-chain carrier to move the silage to the unloading end. Some boxes have cross-conveyors at the end to unload the silage, while other types open the whole endgate.

Field Flail Forage Harvesters. As stated above the flail-type field forage harvester uses free-swinging chains, hammers, or knives to sever the plants by a beating or cutting action. At the time the plants are being

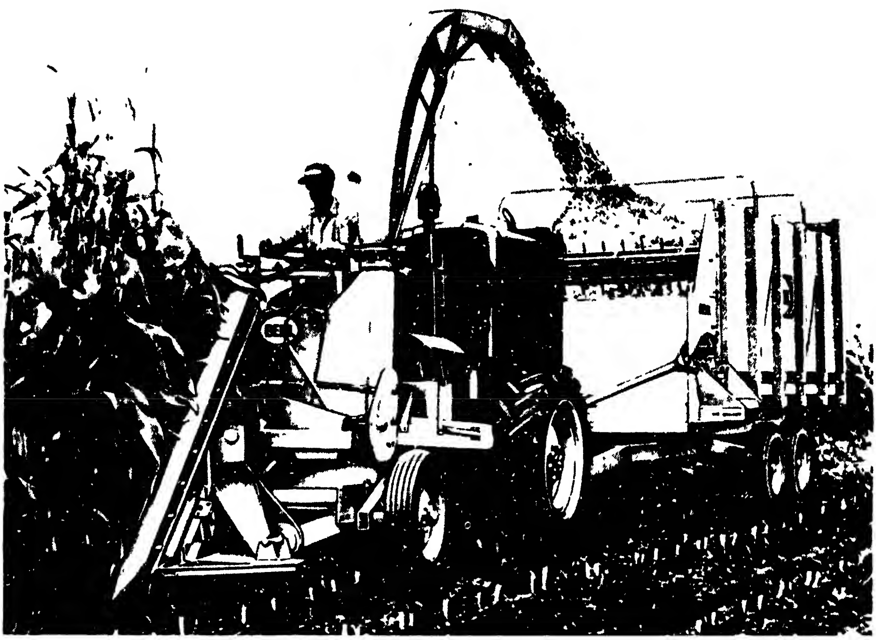

Fig. 17-5. Self-propelled forage harvester cutting corn for silage. A self-unloading forage wagon is pulled behind the harvester.

severed, the flails or knives travel in the same direction the machine is moving (Fig. 17-4). The flail chopper does not have chopping knives on the blower fan to chop the material into acceptable lengths for silage (Fig. 17-4). Where just the flails are used for severing the plants, the harvested material can be blown into windrows for curing. The beating by the flails more or less conditions the hay.

The Self-propelled Forage Harvester. Figure 17-5 shows a self-propelled forage harvester equipped with row-crop attachment. Cutter bar and windrow pickup attachments can be interchanged for the row-crop attachment.

SILO FORAGE BLOWERS

Field-chopped forage is elevated into upright silos by stationary blower units at the silo. Some blowers are equipped with short auger conveyors for the side-unloading wagon boxes. Other blowers have long belt-type conveyors for the wagons that open the endgate (Fig. 17-6).

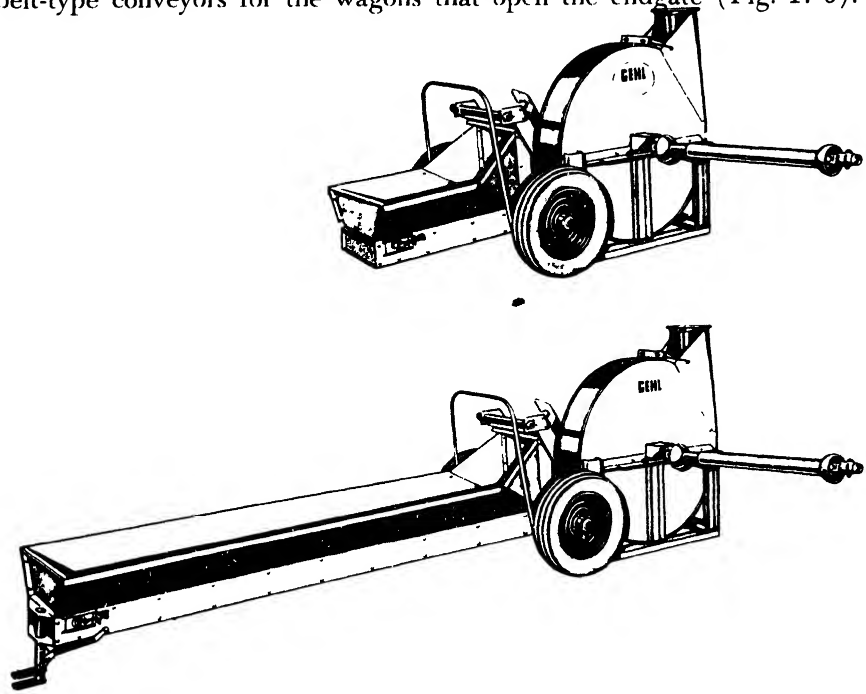

Fig. 17-6. Long- and short-hopper forage blowers (*Gehl Bros. Mfg. Co.*)

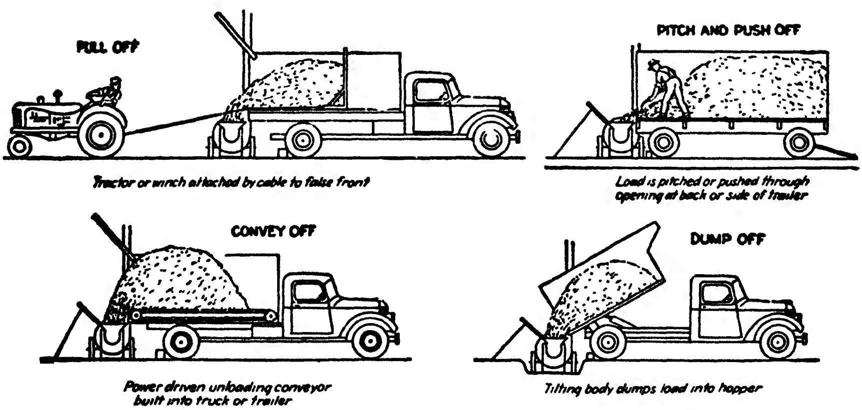

Fig. 17-7. Four methods of unloading chopped silage into blower.

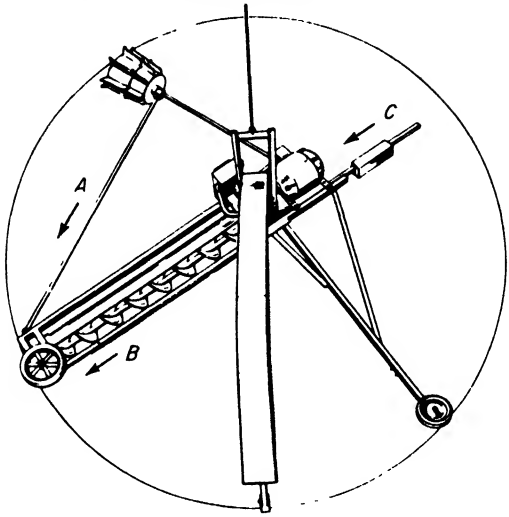

Fig. 17-8. An electrically operated silo unloader showing 9-inch auger. (*Brillion Iron Works, Inc.*)

Fig. 17-9. Mechanical trench silo unloader that cuts loose the packed silage and elevates it into a truck or trailer box. (*Oswalt Industries, Inc.*)

The blowers can be operated by the power take-off or belt pulley of a tractor or by auxiliary engine. Blowers are equipped with a roller feed mechanism and an easily reached clutch lever for engaging and reversing the feed belt or auger.

The combination suction blower can be used for filling both upright and trench silos. It is also useful for unloading seed cotton from trailers into piles. This type of suction blower can be integrally mounted on a tractor.

Figure 17-7 shows several methods of unloading truck and trailer loads of chopped forage into blower conveyors.

SILO UNLOADERS

A silo unloader installed in an upright silo will eliminate the hazards of climbing up into a silo and the labor involved in pitching the silage out manually (Fig. 17-8). An electric motor operates two knife-studded augers which feed the silage to a blower located at the center of the silo. The driving roller moves the augers around so that the silage is removed layer by layer. The whole unit is suspended by a cable from a special tripod at the top of the silo.

The machine shown in Fig. 17-9 is equipped with a power-operated digging and cutting reel to cut and loosen packed silage in a trench silo. The loosened silage falls into a hopper and onto an elevating belt that conveys the silage up and deposits it in a truck or trailer box. The cutting reel is mounted on a hydraulically operated boom. Models are designed to mount on tractors or trucks and as self-propelled units.

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QUESTIONS AND PROBLEMS

1. Give several advantages of field forage harvesters.
2. Explain the differences and functions of row-crop and broadcast forage harvesters.
3. List the factors that affect the capacity of a field forage harvester.
4. Explain the operation of unloaders for upright and trench silos.

GRAIN HARVESTING EQUIPMENT

18

In the preparation of many crops for the market, it is necessary that the seed be separated from the stalk on which they grew. All the small-grain crops must have the seed stripped from the straw, corn must be shelled from the cob, peanuts must be threshed or picked from the vines, and cottonseed must be separated from the lint. Different types of machines are necessary for the separation of the seed from the holding agent in the different crops. Generally, very large apparatus is necessary, incorporating a number of different operations in the same machine as the material passes through it.

Formerly, grain was cut with a binder and the bundles carried to a stationary threshing machine where it was threshed and sacked. Under the present farming practices in the United States, the process is reversed; that is, the machine is carried to the crop in the field where it harvests and threshes the crop, places the grain in a tank, and distributes the straw on the land.

HISTORY OF DEVELOPMENT

Development of the Binder. The Biblical story of Ruth tells how grain was harvested with a hand reaper. The hand reaper was used in Europe and America until horse-drawn machinery was adopted. The long-handled scythe was developed toward the end of the Colonial period. The cradle was introduced between 1776 and 1800. McCormick claimed to have demonstrated his first horse-drawn reaper in 1831 but did not obtain a

patent until 1834. Obed Hussey obtained a patent on a reaper in 1833. McCormick built fifty machines in 1845 and about 800 in 1848.[1]

The self-raking reaper appeared about 1854. A platform for manual binding was introduced about 1850. The first mechanical wire-tying mechanism was introduced in 1873. Twine binders were introduced in 1880, but it was not until 1892 that Appleby obtained a patent on a twine knotter.

The horse-drawn grain binders were ground driven. Auxiliary engines were mounted on some binders about 1920. The power-take-off-driven binder was introduced in the late 1920s.

Development of the Thresher. Rogin quotes William Darling as follows: "In Bedford County, Pennsylvania, grain was still generally threshed with the flail in 1829." Much grain was trodden out by horses in the late 1830s. Other men were granted patents, but the patent granted to Hiram A. and John A. Pitts, Dec. 29, 1837, was the beginning of the thresher. It was horse-operated. The manufacture of the Case thresher was begun at Racine, Wisconsin, in 1844. By 1900, threshers were equipped with self-feeders, band cutter knives, weighers, and wind strawstackers.

Development of the Combine. A patent on what was termed a *combined harvester-thresher* was granted to Samuel Lane in 1828. The real beginning of the combine for harvesting, threshing, and cleaning was when A. Y. Moore et al. of Kalamazoo, Michigan, obtained a patent in 1835. In 1854, 600 acres of wheat were combined in Alameda County, California, but the method was not truly initiated in California until about 1880. One of the earliest manufacturers of horse-drawn traction-driven combines was the Stockton Combined Harvester and Agricultural Works of California. Steam-tractor-drawn combines were introduced in the 1890s. Some of these machines were equipped with a 42-foot header and harvested, it was claimed, from 90 to 125 acres in a day.[2,3]

Gasoline-tractor-drawn combines were introduced on a large scale in the wheat areas of the Middle West as the result of labor shortages during the First World War, or about 1916. Combines were first introduced in northwest Texas in 1919, when seven machines were used.[2] The self-propelled combine was commercially introduced about 1938.[4]

[1] Leo Rogin, *The Introduction of Farm Machinery*, University of California Press, Berkeley, Calif., 1931.

[2] Leo Rogin, *The Introduction of Farm Machinery*, University of California Press, Berkeley, Calif., 1931.

[3] H. P. Smith and Robert F. Spilman, Harvesting Grain with the Combined Harvester-thresher in Northwest Texas, *Tex. Agr. Expt. Sta. Bul.* 373, 1927.

[4] Chris Nyberg, Highlights in the Development of the Combine, *Agr. Engin.*, 38(7):528–529, 1957.

GRAIN COMBINES

The combined harvester-thresher, or *combine,* heads the standing grain, threshes it, and cleans it as it moves over the field. Therefore, it takes the place of and eliminates from the harvest the grain binder, the header, the stationary thresher, and the tiresome tasks of shocking or stacking the grain and hauling the bundles.

The combine is adapted to harvesting all the small grains, soybeans, grain sorghums, rice, as well as many other crops.

Advantages of the Combine. In comparison with other methods of harvesting and threshing, as reported by farmers, the advantages are:[5]

1. The saving in harvesting and threshing costs
2. The decreased labor
3. The elimination of hired help
4. The earlier clearing of the field for tillage operations
5. The distribution of the straw on the land
6. The earlier marketing of the crop

Disadvantages of the Combine. The disadvantages of the combine are:

1. The large investment necessary
2. The large amount of power required
3. The greater likelihood of the grain being damp
4. Greater risk to crops from storms and hail
5. The loss of straw for feed and bedding unless additional labor is expended in collecting the straw after the combine

Types of Combines. There are two general types of combines, the *pull* or *tractor-drawn* and the *self-propelled.*

The Pull-type Combine. The pull-type combine is drawn by a tractor. The smaller combines are driven from the power take-off of the tractor, while the larger sizes have an auxiliary engine mounted on the combine to drive it. Pull-type combines range in size from a 4- to 8-foot cut for the smaller sizes and from a 10- to 20-foot cut for the larger sizes. Gatherers at each end of the cutter bar enable the average machine to cut a swath from 6 to 9 inches wider than the actual length of the cutter bar.

The Self-propelled Combine. Self-propelled combines are powered with industrial-type engines of 45 to 105 horsepower. The self-propelled combine is operated by one man. It is easy to handle and transport from field

[5] L. A. Reynoldson and W. R. Humphries, Shall I Buy a Combine? *U.S. Dept. Agr. Farmers' Bul.* 1565, 1928.

to field and over the highway. A swath can be laid out without loss of grain. Sharp turns can be made to follow rice levees. It is provided with a gearshift to give desired field and road speeds. There is also a reverse gear. Grain self-propelled combines can be obtained in sizes to cut swaths from 6 to 22 feet.

The operator of the self-propelled combine sits above and just behind the electrically or hydraulically controlled platform. The general operation is somewhat like that of a tractor. The machine is steered by means of a large steering wheel connected to the wheels in the rear. If sharp or right-angle turns are to be made, wheel brakes assist in making the turn, similarly to the row-crop tractor. The engine can be started by pressing

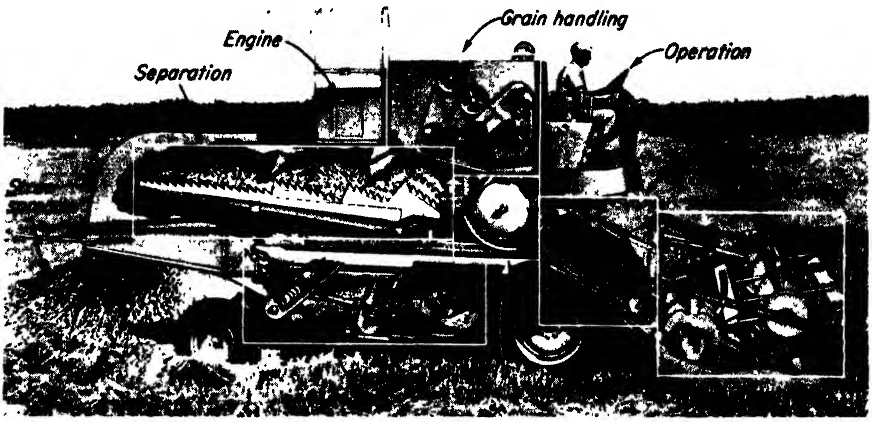

Fig. 18-1. Cross section of self-propelled combine showing the functional areas for cutting, elevating and feeding, threshing, separating, cleaning, and grain handling. (*International Harvester Company.*)

a button, which actuates the self-starter. Transmission and separator clutch levers are conveniently located to control machine travel and operation (Fig. 18-1). A slight movement of a lever on the steering post enables the operator to raise and lower the platform to meet changing conditions in the field. Field speeds range from 1¼ to 4 m.p.h., while road speeds range from 2½ to 13 m.p.h. No changes need be made in the machine for short-distance transportation over highways other than raising the platform and shifting into road gear. Some of the self-propelled combines are designed to operate on hillsides. The combine wheels are adjusted to suit the slope of the land by hydraulic rams. The cutterhead can be tilted to cut on slopes up to 55 degrees. The threshing, separating, and cleaning units are kept level.

Functions Performed by a Combine. The basic operational functions of a combine can be divided as follows: (1) cutting the standing grain, (2)

feeding the cut grain to the cylinder, (3) threshing the grain from the stalk or stem, (4) separating the grain from the straw, (5) cleaning the grain by removing chaff and other foreign matter, and (6) grain handling from combine to tank and from tank to truck (Fig. 18-1).

The Cutting Mechanism. The standing grain is handled by a cutter bar and a reel to sweep the grain back onto a canvas or auger table or platform (Fig. 18-1). The knife usually extends the full width of the cutter bar, which ranges from 4 to 22 feet. It is usually operated by a rocker arm pitman that gives a 6-inch stroke across two guards. The knife sections are serrated. On some combines the cutting mechanism can be angled to cut on sloping land.

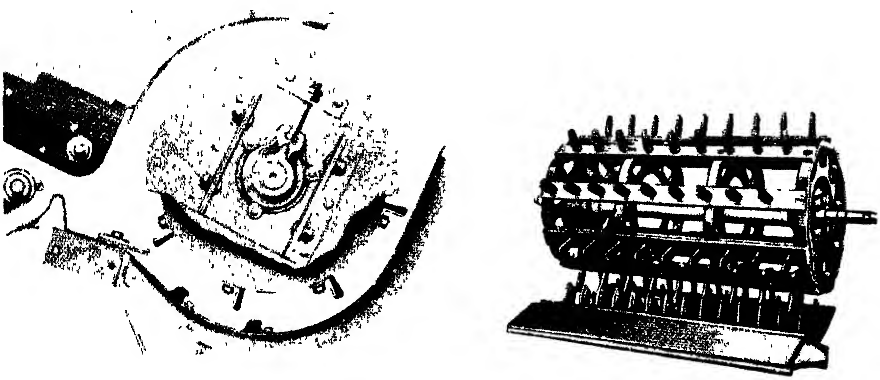

Fig. 18-2. Two types of threshing cylinders: *left,* rubber-type cylinder and concaves; *right,* iron-tooth-type. (*Allis-Chalmers Mfg. Co.*)

The reel is located above the cutter bar and ranges from 40 to 60 inches in diameter. It may have four or six wood bats. Under some conditions canvas or rubber strips are attached to the bats to aid in sweeping the cut material back onto the table or platform. The entire reel can be adjusted up and down as well as back or forward of the cutter bar. Different crops and growth conditions require different positions of the reel. Gass[6] found that for most conditions in combining barley the reel peripheral speed should be 1.25 to 1.5 times the forward speed of the combine. On some narrow-cut machines the platform-feeder canvas is as wide as the cutter bar swath and conveys the cut material direct to the threshing cylinder. Most wide-cut combines have right- and left-hand augers that feed the cut material to the central elevator-feeder belt (Fig. 18-1). The augers vary in diameter from 16 to 20 inches.

[6] J. R. Gass, R. A. Kepner, and L. G. Jones, Performance Characteristics of the Grain Combine in Barley, *Agr. Engin.,* 39(11):697–702, 1958.

Grain-lifting fingers can be attached to the cutter bar to lift fallen grain. A windrow pickup can be attached to pick up windrowed grain.

The entire cutting mechanism, or cutterhead, is usually controlled by hydraulic or electric lifts.

Threshing Mechanism. The threshing mechanism, which separates the grain from the stalks, consists mainly of a revolving cylinder and the concaves (Fig. 18-1). A feeder-beater is usually located in front of the cylinder and at the upper end of the elevator-feeder to assist the elevator-feeder in feeding the grain to the threshing mechanism. Most combines are provided with the rasp-bar-type cylinder and concaves (Fig. 18-1). The grain is rubbed from the stems without materially cutting the straw. Tooth-type cylinders and concaves are available on some combines (Fig. 18-2). One make of small combine uses rubber-faced steel bars for the cylinder and block rubber bars for the concaves (Fig. 18-2). Adjustments are provided for varying the speed of the cylinder to suit the kind of crop being harvested. V-belt drives are used on most combines. The straw is thrown back onto the separating mechanism, while the grain falls through the concaves onto a grain pan or grain carrier and is conveyed to the cleaning mechanism.

On the small straight-through combines, the cylinder and concaves extend almost the full width of the cutter bar, while on the larger machines, the cylinder and concaves are only about 30 inches in width and 18 to 24 inches in diameter. All machines provide means of adjusting the concaves to the cylinder. The peripheral speed of combine cylinders ranges from 2,000 to 7,000 r.p.m., depending upon the type of crop and its condition.

Separating Mechanism. The main separation of the grain from the straw is through the concaves. The loose grains, which are mixed with the straw as it leaves the cylinder, are separated by oscillating straw racks. These racks may consist either of one piece or of several sections which alternately move with a slight elliptical action to pitch the straw rearward with each movement (Fig. 18-1). If the straw racks are made in sections, a long, revolving crankshaft is used to operate them. The pitching action of the straw racks sifts the loose grain from the straw and lets it fall onto a grain pan underneath.

A straw beater is usually located just to the rear of the cylinder to beat out loose grains. One or two steel and canvas curtains hang down from the top housing to deflect and keep the straw in contact with the straw racks (Fig. 18-1).

Cleaning Mechanisms. The function of the cleaning unit is to remove chaff and other foreign matter from the grain. This is accomplished by passing the uncleaned grain over a series of oscillating sieves and screens through which a current of air is forced by a fan (Fig. 18-1). Different

types of sieves and screens are available for different kinds of crops. Partially unthreshed heads of grain, termed *tailings,* drop into an auger which delivers the tailings to an elevator which in turn conveys the material upward to be rethreshed by the cylinder.

Attachments for Combines. A number of attachments can be obtained for combines. These include a straw spreader (Fig. 18-1), straw windrower, straw loader, straw chopper, windrow pickup, windrow spreader, bundle-topping vertical cutter bar, flax roller, bagger, grain bin, cylinder-speed tachometer, and a Scourkleen for the removal of weed seeds (Fig. 18-3).

The grain tank is usually provided with a power-driven auger for transferring the grain from the tank to a grain cart or truck (Fig. 18-1).

Fig. 18-3. A Scourkleen attached above the grain bin or bagging attachment cleans weed seeds from grain.

Harvesting Corn with Combines. Most self-propelled combines can be equipped with a corn harvesting attachment (Fig. 19-3). The speed of the cylinder and the adjustments of the concaves and screens are changed to suit the conditions.

Harvesting Sorghum Grain and Soybeans. Sorghum grain and soybeans are harvested with the grain combine with minor adjustments in speed of the threshing cylinder and the sieves and screens.

Windrowing Machines. In some areas, farmers find that cutting and windrowing the top portion of the plants with the grain attached permit earlier harvesting and protect the grain under the following conditions: (1) when the grain is unevenly ripened, (2) when fields are weedy, (3) when the straw is green but crop ripe, (4) when the grain is high in moisture, (5) when crop conditions are such that legume crops tend to shatter if left until ripe, and (6) when weather conditions delay direct combining. The windrowing machine consists of a power-take-off-driven knife, platform canvas, and reel.

The heads of grain are clipped off and fall upon the traveling platform canvas which delivers the grain over one end onto the stubble. Most

windrowing machines deliver the grain over the end farthest away from the standing grain. Center-delivery machines are available.

The Rice Self-propelled Combine. The principal outside differences between a regular grain combine and a rice combine are in the size and arrangement of the wheels. The regular-grain self-propelled combine is equipped with medium-sized tires (Fig. 18-1). The main wheels of the rice self-propelled combine are equipped with large, deep mud lugs to enable the combine to climb over the narrow contour levees needed in

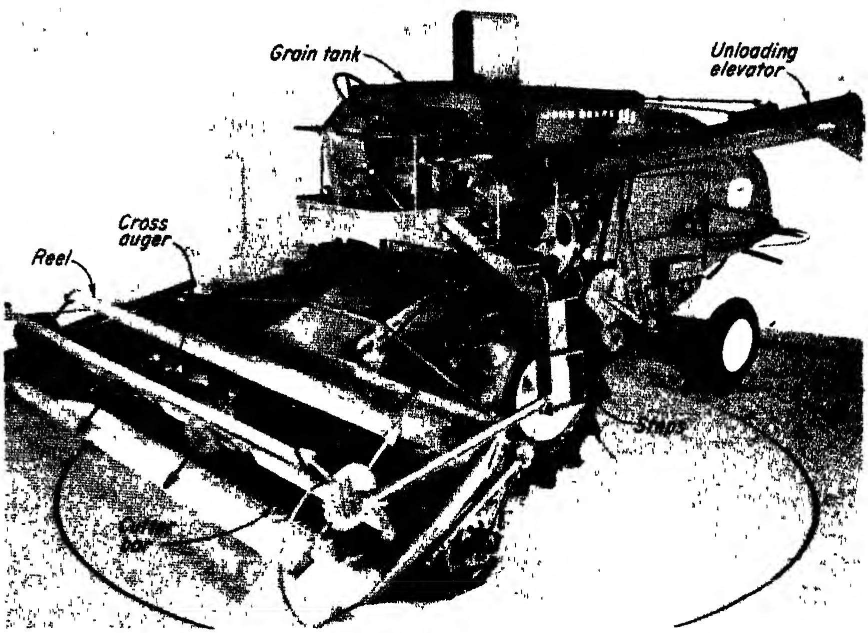

Fig. 18-4. Showing the outside appearance of a self-propelled rice combine. Note the large rubber tires with mud lugs and the large grain tank. (*Deere & Co.*)

flooding rice fields and to give traction in muddy, poorly drained fields (Fig. 18-4). Some rice combines are equipped with tracks (Fig. 18-5). It is claimed that the tracks operate better than tires in some soils. Tires on the combines are more satisfactory for traveling from field to field and for transportation over the highway, as they are faster and do not shake the machine so badly. The rice self-propelled combine is equipped with an engine of greater horsepower than the grain combine because more power is required to travel over the soft rice fields.

Rice combines were used extensively in south Texas for the first time in 1943. It is estimated that 60 to 70 per cent of the rice crop was har-

vested with combines in 1945 and 98 per cent in 1953. The use of the combine has brought about revolutionary changes in handling this crop. Formerly all the rice was handled in sacks; now it is handled in bulk like wheat. Rice carts (Fig. 18-6) have been developed to get the rice from the combine out in the wet, muddy field to a truck located on a graded field road. Furthermore, when rice is harvested, there is too much

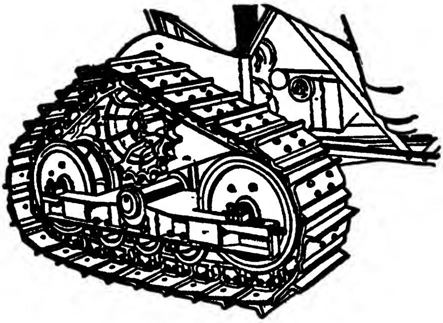

Fig. 18-5. Special tracks used on some self-propelled combines.

Fig. 18-6. Special rice carts for transporting the rice from the combine in the field to trucks located on a field road.

moisture in it for it to be stored, and consequently, it must be dried. There are now many large commercial rice dryers throughout the rice-growing regions of Texas, Louisiana, and Arkansas.

Design, Costs, Adjusting, and Duty of Combines. *Basic Design Requirements of Combines.* Carroll[7] states that the basic design requirements for self-propelled units are as follows:

[7] Tom Carroll, Basic Requirements in the Design and Development of the Self-propelled Combine, *Agr. Engin.*, 29(3):101–105, 1948.

1. Accessibility
2. Simplicity, with easier and simpler adjustments
3. Complete ease of control and comfort for the operator
4. Capacity to harvest all crops under every condition encountered throughout the grain-growing countries of the world
5. Lighter weights and greater capacity in relation to width of cut
6. Working speeds from ½ m.p.h. to a maximum of 5½ m.p.h., with a road speed of 7 m.p.h.
7. Sufficient engine power to take care of difficult ground conditions as well as to operate the combine mechanism
8. Proper weight distribution in relation to wheels
9. Attachments, drives, and straw-handling equipment
10. Necessary traction equipment for rice fields

Cost of Combining. The various items of cost in harvesting with a combine are *operating* and *fixed* costs. Operating expenses consist of the costs of fuel and lubricants, use of tractor, labor, and repairs. Fixed charges are for depreciation, interest on investment, taxes, insurance. The cost of housing may also be added. The profit which a self-propelled combine can return to the farmer is measured by the time and labor saved and the increased return resulting from the use of added power.

TABLE 18-1. COMPARISON OF CALCULATED COSTS, IN DOLLARS PER ACRE, OF HARVESTING WITH SELF-PROPELLED AND PULL-TYPE COMBINES

Acres per year	Self-propelled		Pull-type		
	Base costs	Base costs less tractor credit	Base costs	Base costs and field-opening loss	Base costs and field-opening and transport loss
20	$21 55	$21 30	$10 30	$11 30	$12 30
50	9 00	8 75	4 80	5 30	6 30
100	4 80	4 55	2 80	3 30	4 30
150	3 40	3 15	2 15	2 65	3 65
200	2 70	2.45	1 80	2 30	3 30
250	2.30	2 05	1 60	2 10	3 10
300	2.00	1 75	1 50	2 00	3 00
350	1 80	1.55	1.40	1 90	2.90
400	1 65	1.40	1.30	1 80	2.80

SOURCE: E. L. Barger, Engineering-Management Aspects of Self-propelled Farm Machines, *Agr. Engin.*, **29**(3):106, 1948.

The data in Table 18-1 show the comparative cost of combining with self-propelled and pull-type combines. The graph in Fig. 18-7 shows that the cost of combining with the self-propelled type is higher for the lower

acreages but becomes lower than for the pull-type when 250 or more acres are harvested.

Adjusting the Combine. If losses are to be reduced to a minimum, the various units of the combine must be carefully adjusted. An explanation of these adjustments requires more space than can be taken in a text. Therefore, as each make of machine has different means provided for making the adjustments, the operator should carefully study the operator's manual and make the adjustments in order from front to rear of the machine, including the power mechanism. Adjustments will not cure all the troubles, because if the machine is driven too fast or the cutter

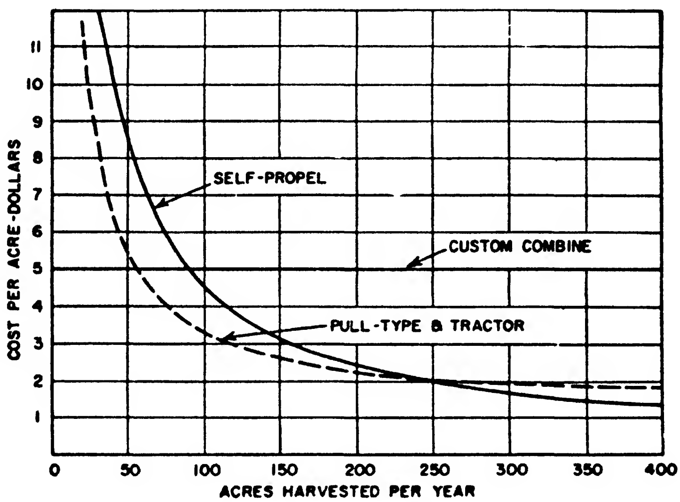

Fig. 18-7. Comparison of harvesting costs, including credit to the self-propelled combine for releasing a tractor and charging the pull-type for both field-opening losses and a sum representing inconvenience losses. [*Agr. Engin.*, 29(3):107, 1948.]

bar set too low, the machine will be overloaded and excessive losses of grain will occur as shown in Fig. 18-8.

Acres Cut by Combines. Most people think of the capacity of a machine as the amount of work it can do in a day's time. The principal factors that influence the rate of cutting are the size of the machine, rate of travel, and yield of grain.

Reynoldson, Kifer, Martin, and Humphries[8] calculated, from 214 reports of combines equipped with auxiliary engines, that the rate of cutting would be increased 0.27 acre per hour by the addition of each foot to the

[8] L. A. Reynoldson, R. S. Kifer, J. H. Martin, and J. H. Humphries, The Combined Harvester-Thresher in the Great Plains, *U.S. Dept. Agr. Tech. Bul.* 70, p. 14, 1928.

length of the cutter bar. The average cut per hour for each foot of width was approximately 0.23 acre. The rate of cutting depends upon the rate of travel and upon the size of the machine.

They also stated that

> . . . on this basis a 10-foot machine in 20-bushel wheat, traveling 2.5 m.p.h., should cut 20.5 acres in a 10-hour working day. A 12-foot machine should cut 25.9 acres, a 15-foot machine 34 acres, a 16-foot machine 36.7 acres, and a 20-foot machine 47.5 acres.
>
> A 10-foot combine should harvest 357 acres in a 15-day harvest season. The minimum profitable acreage in the Great Plains for a machine of this size is about 150 acres; the maximum is about 640 acres. A 15-foot combine should harvest 525 acres in 15 days, with a minimum of 200 and a maximum of 1,100 acres.

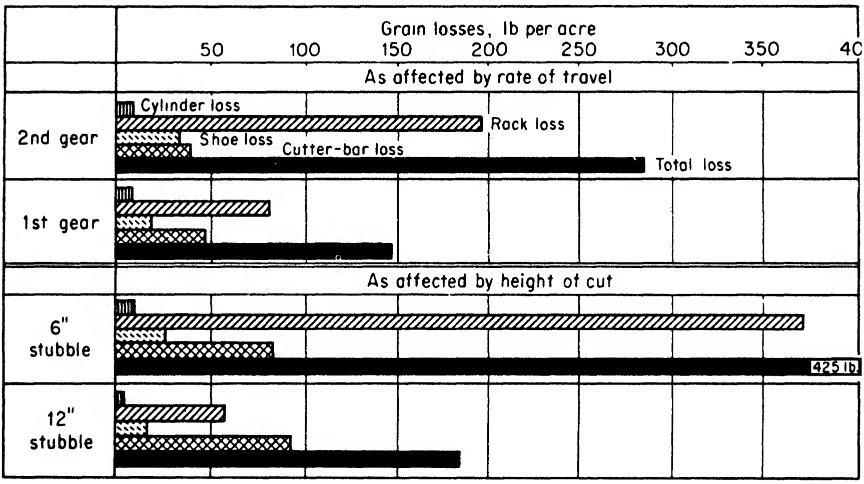

Fig. 18-8. Overloading grain losses as affected by height of cut and rate of travel. (*Ohio Agr. Ext. Bul.* 330, 1952.)

Self-propelled combines with a 14-foot cutter bar can harvest small grain and sorghum at the rate of 40 to 50 acres per day. When rice was harvested in soft fields and where contour ridges had to be crossed, 27 acres were harvested per day with a 14-foot self-propelled combine.

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QUESTIONS AND PROBLEMS

1. Trace the development of the combine.
2. Explain what is meant by the term combine. Give the advantages and disadvantages of this type of machine.
3. Describe the different types of combines.
4. Explain the various functions performed by a combine.
5. Explain why a windrowing machine is used in some areas.
6. What are some of the basic design requirements of combines?
7. How many acres can be harvested in a 10-hour day with a 14-foot combine traveling at 2.5 m.p.h. in harvesting 20-bushel wheat? Allow 85 per cent for field efficiency.
8. What are the basic design requirements for a self-propelled combine?

CORN HARVESTING EQUIPMENT

19

The corn picker is a single- or double-row machine equipped with snapping rolls to remove the ears from the standing stalks. As the corn picker is a great time and labor saver, it is being used extensively to replace the slow, hard hand method of harvesting. Only one man is required to operate any of the power-driven one- and two-row pickers shown in Fig. 19-1. Additional help may be required to haul the corn and place it in the bin. Most machines do not sever the stalks from the ground. The gatherer sides and chains guide the stalks into the throat between the downwardly revolving snapping rolls, which pinch and snap the ears from the stalk. The ears are deflected into an elevator system which conveys them to a wagon or trailer drawn either beside or behind the machine. The ears can also be snapped, husked, and shelled in a continuous operation.

History of Development. The corn picker was first invented by Quincy in 1850. William Watson of Chicago invented a corn picker shortly after Quincy's invention. The snapping-roller-type corn picker was developed by manufacturers about 1874, but it was not patented until about ten years later. The rollers were placed in an incline position. Because of the development and the use of the corn binder, interest in corn pickers lagged until about 1920, when manufacturers introduced several new machines. The early makes of corn pickers were ground driven by means of a large bull wheel. Tractor pull-type power-take-off-driven corn pickers and the tractor-mounted picker were introduced about 1930. A self-propelled corn picker was made available about 1950.

Types of Corn Pickers. Machines are available for harvesting ears of corn in three different ways. The simplest machine snaps the ears from the stalks and does not remove the husks. This type of machine is called a *snapper*. Most machines used in the Corn Belt are also equipped with a husker attachment which, in addition to snapping the ears from the plant, also removes the husks. This type of machine is called a *picker-husker*.

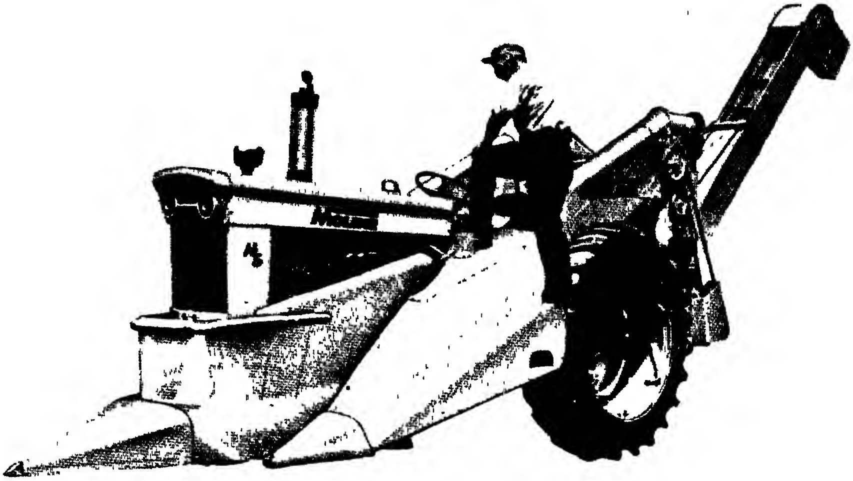

Fig. 19-1. Two-row tractor-mounted corn-picker-husker showing how operator can get to the tractor seat by using recessed steps in the outer divider and tractor-wheel shield. (*Minneapolis-Moline Division, Motec Industries.*)

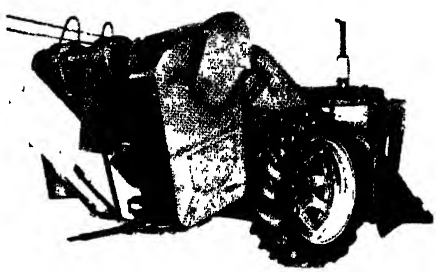

Fig. 19-2. Rear view of two-row tractor-mounted corn-picker-sheller showing the shelling attachment. (*International Harvester Company.*)

A more recent development is a machine that snaps the corn and shells it in the field. This type of machine is called a *picker-sheller*. Generally, however, corn pickers are classified according to the number of rows harvested and the way the machines are attached to the tractor. Figures 19-1 and 19-2 show front and rear views of a two-row tractor-mounted corn picker-sheller. The pull and tractor-mounted types each have their advantages and disadvantages. The pull types are unit machines which

can be easily attached and detached from the tractor. With them, however, the operator must look back and to the side to watch the machine. At least three unpicked rows of corn are broken down by the tractor and wagon in opening a land through the field. With the tractor-mounted type, time is required to mount the machine, and the tractor cannot very well be used for other work while the machine is mounted. Some machines are more easily mounted than others. But with the tractor-mounted machine, the operator can steer the tractor and watch the machine with-

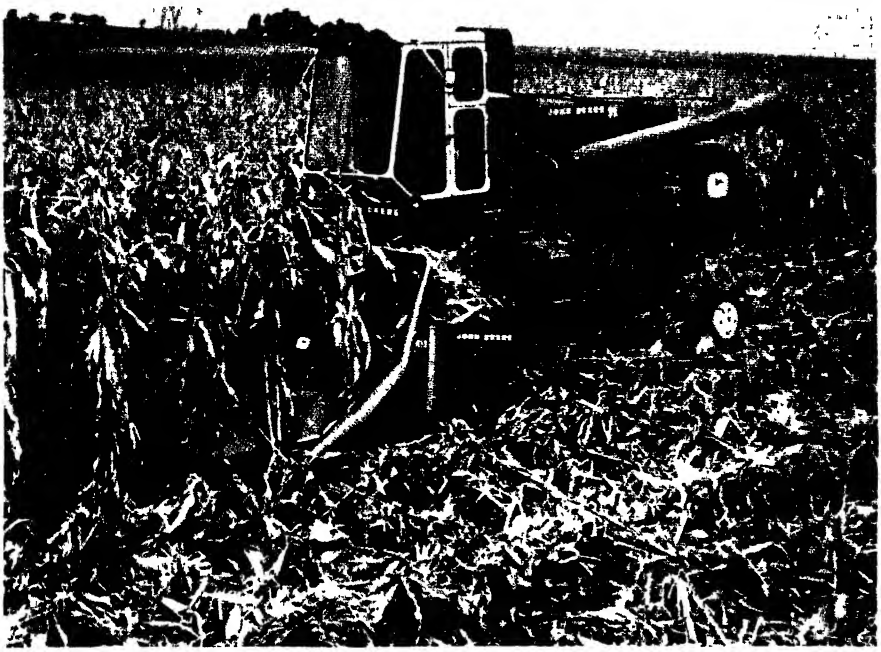

Fig. 19-3. Self-propelled combine equipped with four-row corn harvester attachment. (*Deere & Co.*)

out any neck twisting. With this type of picker, too, a land can be opened through the field without breaking down extra rows. The wagon or trailer is drawn behind the machine.

Figure 19-3 shows a combine equipped with a four-row corn-snapping attachment. The ears are fed into the threshing cylinder where they are shelled. The husks and cobs pass out over the straw racks, while the shelled corn flows through the cleaning unit and up to the grain tank.

Under favorable conditions and high yields a large combine fitted with a four-row corn-snapping attachment can harvest 3,000 to 4,000 bushels of corn per day.

Self-propelled corn picker-shellers are available, but their use is limited since the development of the corn attachment for self-propelled combines. The corn-snapping attachments can be purchased for much less than a corn picker-husker-sheller.

Power Transmission. The early makes of corn pickers were horse-drawn and ground driven. The present pull types are power take-off driven. The power is transmitted from the tractor by means of a long drive shaft to a gearbox on the picker, from which the various parts of the picker are driven. The tractor-mounted types require short drive shafts, countershafts, and chain and belt drives. Slip or jump safety clutches are provided for each of the functional parts.

The Gathering and Snapping Mechanism. There is no difference in the gathering and snapping mechanism of the one- and two-row pull types and tractor-mounted types, except that, for the two-row pickers, an extra unit is added. On a two-row picker, the middle divider point is always hinged, while the side gatherers on the one- and two-row pickers may or may not be hinged (Fig. 19-1). The hinging of the points permits them to be set close to the ground and to follow the contour of the surface, thus slipping under and picking up stalks lying close to the ground. As the stalks are guided into the throat by the *gatherer* points, lugged gatherer chains assist in feeding the stalks in between the snapping rolls. Spiral lugs (Figs. 19-4 and 19-5) on the downwardly moving adjacent sides of the snapping rolls catch the stalks, pull them down, and discharge them under the machine. The design and shape of the corrugated lugs on the snapping rolls differ with the various makes of machines. As the stalks are pulled down between the snapping rolls, the ears are pinched off. Ordinarily, the outside roll is set a little higher than the inside roll, and this aids in deflecting the ears into the conveyor elevator to one side if it is a one-row picker and in between the units if a two-row picker.

The snapping rolls should be adjusted as close together as conditions of the crop and the design of the rolls will permit. Some picker-husker corn pickers have the snapping rolls extended to form husking rolls (Fig. 19-5).

Two-row corn pickers are designed so the units can be adjusted to harvest row spacings from 38 to 42 inches apart. One make has an arrangement whereby the snapping rolls can be adjusted closer or farther apart by means of levers within the convenient reach of the operator. The adjustment can be made while the machine is idle or while in operation.

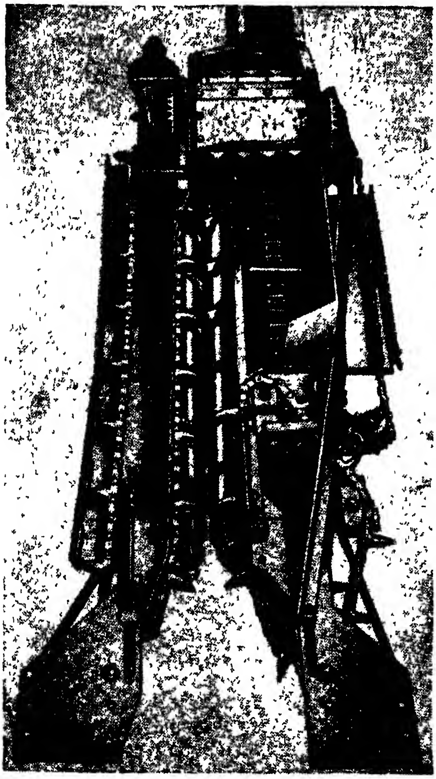

Fig. 19-4. Corn-picker unit with shields and gathering points removed to show gathering chains, snapping rolls, and conveyors. (*International Harvester Company.*)

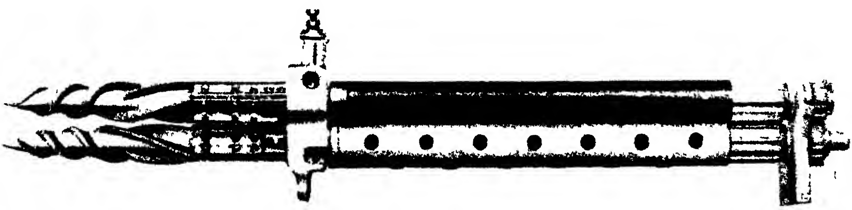

Fig. 19-5. Combination snapping and husking rolls for corn-picker-husker. (*Allis-Chalmers Mfg. Co.*)

Some makes of corn pickers have trash knives installed under the snapping rolls to cut off vines, grass, and stalks that tend to wrap around the rolls under damp conditions. Other makes have trash rollers at the rear end of the snapping rolls to remove trash and broken stalks (Fig. 19-6). Figure 19-7 shows snapping bars or stripper plates mounted above the rolls to aid in snapping the ears from the stalk.

The Conveying and Elevating Mechanism. As the ears fall from the snapping or husking rolls, they are conveyed back and elevated so they can be dropped either through an air blast into the wagon elevator or into the husker or sheller units.

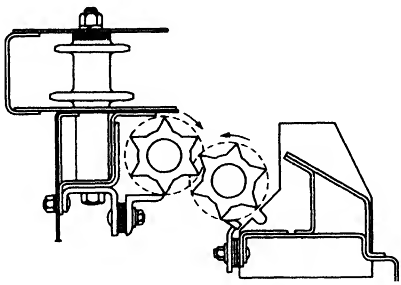

Fig. 19-6. Weed knives mounted under the snapping rolls prevent weeds and vines from winding around the rolls.

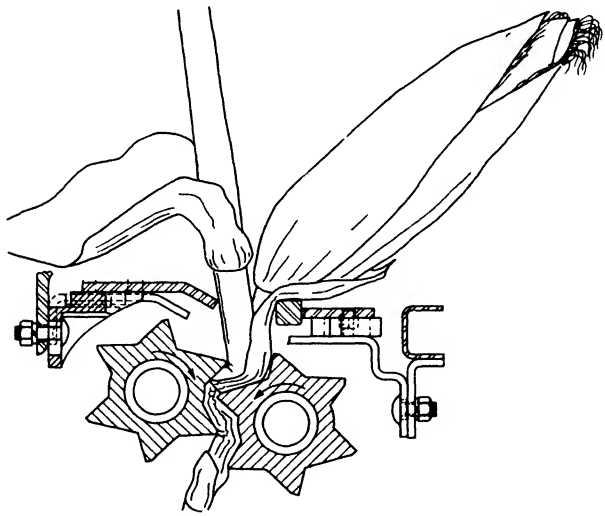

Fig. 19-7. Snapping or stripping plates mounted above the snapping rolls aid in snapping off the ears without husking, pinching, and shelling of the butts and tips of the ears.

The Husking Mechanism. The husking rolls may be set in line with the snapping rolls, or they may be part of an interchangeable attachment set across the rear of the machine. The husking rolls, as shown in Fig. 19-8, operate in pairs, with each pair held together under a spring pressure which can be regulated. One of each pair of husking rolls usually is made of rubber or has a rubber covering. There should be just enough tension

on the rolls to cause them, with the aid of corrugations and husking pins on the rolls, to grasp the husks and pull them through the rolls so that the ears are stripped clean with a minimum amount of shelling. Pressure on the retarding plates can be adjusted for large and small ears. The number of rolls in a husker ranges from two to four. Some corn pickers are equipped with a fan to blow the husks and trash off the husking rolls. Any corn shelled by the husking rolls is gleaned as it drops into the grain saver.

The Shelling Mechanism. Figure 19-9 shows a typical corn-sheller unit for a tractor-mounted corn picker-sheller. It consists of a peg-studded

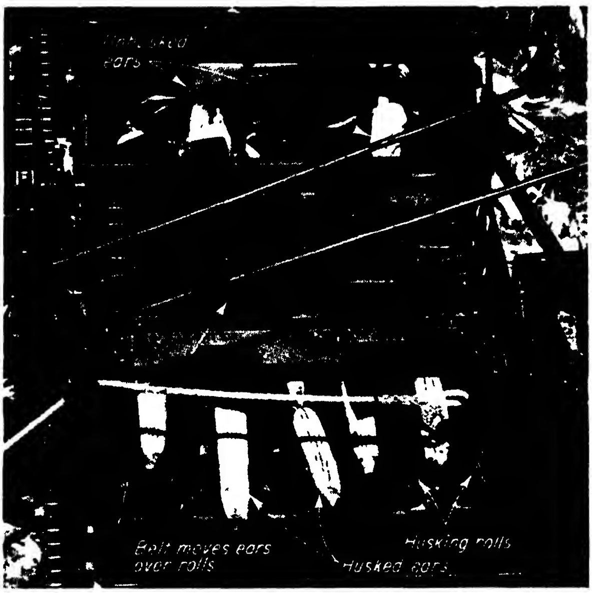

Fig. 19-8. Corn-husking unit for corn picker, showing husking rolls and belt for moving the ears over the rolls. (*International Harvester Company.*)

cylinder about 8 inches in diameter rotating inside a cylindrical screen. The shelled corn drops through the holes in the screen, while the husks, cobs, and fine trash are ejected and blown out the end of the sheller.

Tests conducted by Pickard indicated that a rasp-bar concave clearance of $\frac{5}{8}$-inch was more desirable than a $\frac{3}{4}$-inch, that the critical kernel moisture falls between 30 and 25 per cent, and that a cylinder speed of 800 r.p.m. (3,100 f.p.m. at the periphery) is more desirable than 600 r.p.m. (2,350 f.p.m.).

Factors Affecting Performance of Corn Pickers. There are a number of factors that will influence the performance or efficiency of corn pickers.

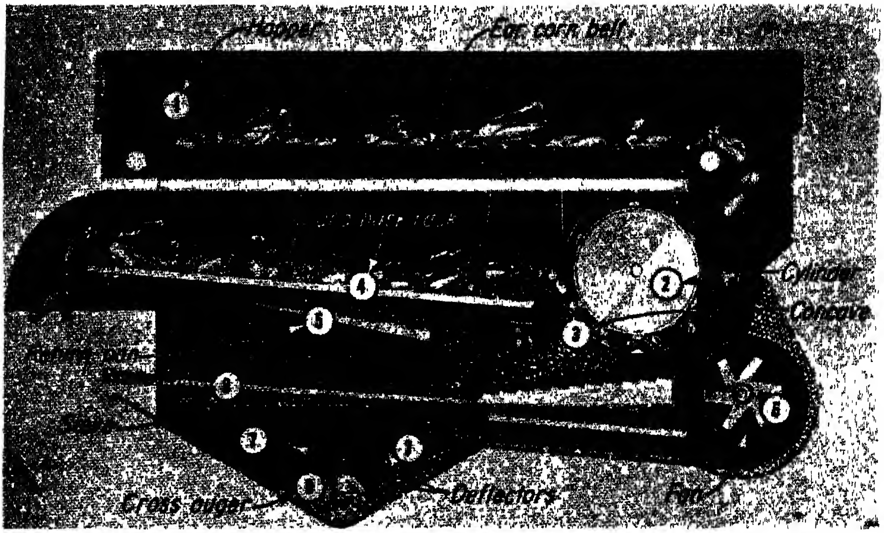

Fig. 19-9. Sectional view of shelling unit for corn sheller. (*Ford Motor Co., Tractor and Implement Division.*)

Several are listed as follows:

1. Plant characteristics
   a. Variety or hybrid suitable for machine harvesting
   b. Stiff stalks that stand up and do not break over and lodge
   c. Condition of the stalks
   d. Height of ears and stalks
   e. Toughness of the ear shanks
   f. Size of ears—large ears reduce shelling losses
   g. Hard-shelling characteristics reduce shelling losses
   h. Thick, tight husk on ear desirable for snapping but not for husking
2. Mechanical factors
   a. Type of snapping roll surface
   b. Adjustment of snapping rollers—distance apart
   c. Timing of snapping rollers
   d. Rate of travel
   e. Type of wagon hitch
   f. Adjustment of dividers to pick up stalks which are down
3. Miscellaneous factors
   a. Timeliness of harvest; field loss is less if harvesting is done early
   b. Carefulness of operator
   c. Weather conditions
   d. Cleanliness of fields, that is, freedom from tall weeds and grass
   e. Length of rows
   f. Row spacing suitable for machine

Most of the field losses in snapping ears of corn from the standing plants can be attributed largely to three main factors, namely, (1) down or lodged stalks, (2) timeliness or date of harvest, and (3) rate of travel in harvesting.

Data collected by the author in Texas show that the average percentage of lodged and down stalks in August, September, and October was 12.1, 24.5, and 54.5, respectively. The average percentage of lost corn was 2.9, 7.6, and 12.9, respectively, for August, September, and October. This increased field loss was due largely to the increase in ears lost.

Tests conducted by Burrough and Harbage of Indiana with a picker-sheller show that losses increased for both the snapper unit and the shelling unit as the season became later. They also found that sheller losses

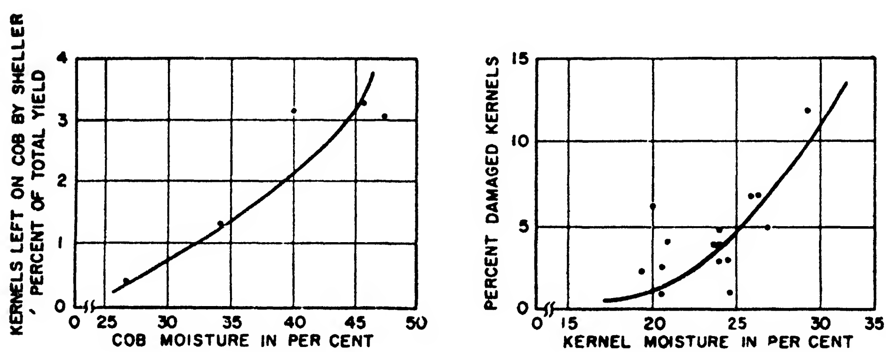

Fig. 19-10. Charts showing how the moisture content of cob and kernel affected sheller loss and kernel damage. [*Agr. Engin.*, 34(1):22, 1953.]

decreased as the moisture content of the cob decreased (Fig. 19-10). Cobs with a high moisture content were spongy and easily broken, and kernels of corn stuck to the whole cob and cob pieces.

Young found that field losses increased as the rate of travel was increased (Fig. 19-11). He recommended that tractors used with corn pickers be operated in first gear.

Methods for Calculating Field Losses. There are several rule-of-thumb methods of quickly calculating the amount of corn being lost by a corn picker. Some are as follows:

1. Twenty kernels of corn to a hill or 3½ feet of row equals 1 bushel per acre loss.
2. One good size ear in forty hills, or 133 feet, equals 1 bushel per acre loss.
3. Shelled corn loss can be determined by counting the number of kernels per square foot. There are approximately 74,052 kernels in a

bushel of average corn. As there are 43,560 square feet in an acre, 1.7 kernels per square foot is a bushel loss per acre. If the rows are spaced 42 inches, or 3½ feet, and 125 kernels of corn are found in 6 feet of row, or $3\frac{1}{2} \times 6 = 21$ square feet of row, $125 \div 21 = 5.95$ kernels per square foot. Thus $5.95 \div 1.7 = 3.5$ bushels of shelled corn loss per acre.

4. The ear corn loss can be estimated by gathering the ears on the ground after harvest in 1/100 part of an acre and multiplying their weight by 100. It is assumed the plot was gleaned for fallen ears before operating the machine.

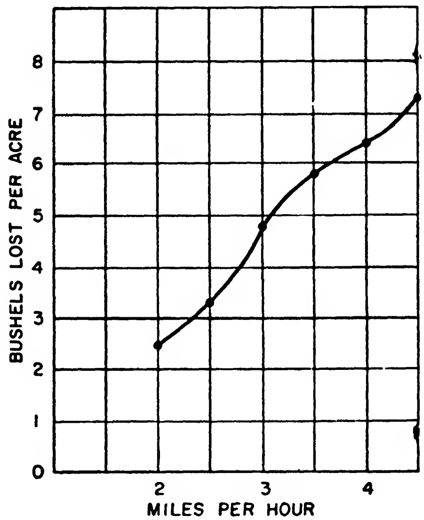

Fig. 19-11. Chart showing the effect of speed of picking on field loss of corn. (*O. L. Young, Illinois State Normal University.*)

Safety Rules for Operating Corn Pickers. Operators of corn pickers have suffered many accidents, probably more than for any other single piece of farm equipment.

The Farm Equipment Institute, working with the National Safety Council, recommends the following safety rules for the safe operation of corn pickers.

1. Keep the picker on the row.
2. Keep the power take-off shaft covered.
3. Keep the snapping rolls in good condition.
4. Be sure the safety clutches are properly adjusted.
5. Keep riders, especially children, off the picker.
6. Don't combine hunting with corn picking.

7. Always shut off the power before dismounting to clean picker if it should clog.
8. Wear snug-fitting clothing.
9. Run the picker at the correct speed for the field conditions.
10. Read the instructions.
11. Don't use a stick to push stalks through the rolls.
12. Watch the roll adjustment and the tension of the gathering chains.
13. Shield the exhaust manifold and the sides of the engine to prevent dry material from collecting and being set on fire.
14. Use a sediment bulb which is not easily broken.
15. Keep fire extinguisher available.
16. Keep the platform of the tractor free of obstructions over which the operator can stumble.
17. The operator should be especially careful when tired.
18. Keep untrained operators off the picker.
19. See that proper lights for night travel are provided.
20. Don't clean, grease, or adjust the machine while the power is connected.
21. The operator should always shut off the power when he gets off the tractor.

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QUESTIONS AND PROBLEMS

1. Explain the differences between the types of corn pickers.
2. Explain the action of the snapping rolls on a corn picker.
3. Discuss the various factors that affect the performance of corn pickers.
4. Give the rule for calculating the field losses for corn pickers.
5. Give fifteen safety rules for operating corn pickers.

COTTON HARVESTING EQUIPMENT

20

A little more than 100 years passed from the time the first cotton-picking machine was developed until cotton farmers began the uninterrupted use of machines for harvesting the cotton crop. During this time, there were hundreds of cotton harvesting machines patented, some of which would, no doubt, do a satisfactory harvesting job today. There were, however, a number of factors that hindered their acceptance and use at the time they were developed. The cotton farmer had an ample supply of relatively cheap labor. He was looking for a machine that would harvest cotton comparable in cleanliness to that of hand-harvested cotton and, at the same time, leave practically no visible cotton along the row. The gins were not equipped with devices to handle machine-harvested cotton. Generally, the cotton farmer was satisfied with hand harvesting his crop —he was not ready for a change.

The scarcity of labor during the Second World War and new developments in harvesting and ginning equipment played a large part in changing the cotton farmer's viewpoint about harvesting cotton with machines. In 1942, a few bales of cotton were harvested with experimental picking machines. In 1953, it is estimated that there were approximately 15,000 mechanical cotton pickers and 25,000 cotton strippers available. These machines harvested about 25 per cent of the 16 million bales produced. In 1962 it was estimated that 60 per cent of the cotton grown in the United States was mechanically harvested.

HISTORY OF DEVELOPMENT

The first patent granted for a mechanical cotton picker was granted to S. S. Rembert and J. Prescott of Memphis, Tennessee, Sept. 10, 1850. Many mechanical, pneumatic, and electrical devices were patented during the century that followed. August Campbell obtained a patent July 16, 1895, on a spindle that has proved to be the basic principle for the successful cotton-picking machine of today. The International Harvester Company acquired the Campbell patents in the early 1920s and spent more than twenty years developing the barbed-spindle machine they placed on the market in 1942. About 1932, John and Mack Rust were granted a patent on a cotton picker which used a smooth, moist spindle.

A machine for the removal of the entire cotton boll from the plant by a stripping action was patented by John Hughes of New Bern, North Carolina, Mar. 28, 1871. Z. B. Sims of Bonham, Texas, obtained a patent, Sept. 3, 1872, on a finger-type cotton stripper that combed the cotton bolls from the plants. The machine patented by W. H. Pedrick of Richmond, Indiana, Jan. 27, 1874, was the first in which revolving spiked rolls were used to remove cotton bolls.

The author, in connection with studies for the Texas Agricultural Experiment Station, developed a smooth-roll tractor-mounted cotton stripper in 1930. The principles of this development were incorporated in the Boone machine in 1943. In 1948, the Oklahoma Agricultural Experiment Station developed a stripping roll using longitudinally extending rows of nylon bristles. In 1952, the author developed a stripper roll using longitudinally extending rubber strips that projected radially from a central core (Fig. 20-1). Patents were granted on this type of roll in 1958.

Several commercial horse-drawn cotton strippers were available from 1928 to 1931. The depression period from 1932 to 1942 caused a lag in both farmer and commercial interest. In 1943, a two-row tractor-mounted stripper equipped with two smooth steel rollers was introduced. In 1944, Deere and Company introduced a two-row tractor-mounted stripper equipped with a single steel roller. During the period from 1946 to 1953, at least seven commercial makes of strippers were introduced.

This brief historical sketch shows that there are available two distinct types of cotton harvesters, namely, the *stripper* type which removes the whole boll from the plant, and the *picker* type, which removes only the locks of seed cotton.

THE COTTON STRIPPER

The first farm-scale use of the mechanical cotton stripper was in northwest Texas about 1914, with a section of a picket fence. Farmers of the

area used narrow boxlike sleds between sorghum rows to collect heads of sorghum grain. An enterprising farmer knocked out the front end of the sled box and nailed some of the fence pickets to the base so that, as the cotton was combed from the plants, he could stand in the box and rake the cotton off the fingers. This method was termed *sledding cotton.* Horse-drawn sled strippers were used extensively from 1925 to 1931. Few were used during the depression period from 1932 to 1942 because of an abundance of cheap labor. Their use was discarded shortly after the appearance of the tractor-mounted stripper in 1943 (Fig. 20-2).

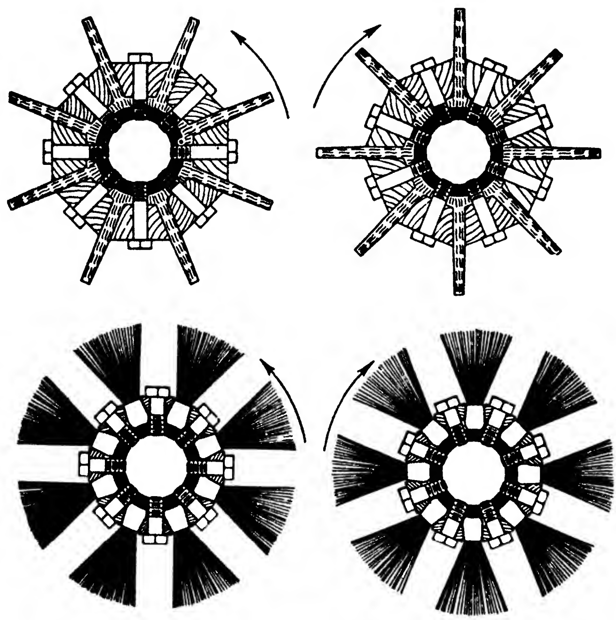

Fig. 20-1. Cross section of brush and rubber-strip-paddle cotton-stripping rolls. (*Texas Agricultural Experiment Station.*)

Types of Cotton Strippers. Cotton strippers are classified largely according to the type of stripping device, such as, the *single steel roller* (Fig. 20-3), the *double steel roller* (Fig. 20-4), the *double rubber-strip* or *paddle roller* (Fig. 20-1), and the *multiple-finger* or *comb types* (Figs. 20-5 and 20-6). Machines using the single steel roller operating opposite a stationary stripper bar have a conveyor on only one side. The conveying device may consist of a series of beaters, or there may be a conveyor-auger (Fig. 20-3).

Factors Affecting the Performance of Cotton Strippers. There are many factors embracing both plant characteristics and mechanical factors that affect the performance of all types of mechanical cotton strippers.

Plant Characteristics. Results of stripping numerous varieties possessing variable characteristics indicate that the desirable plant type for the mechanical cotton stripper is one which has relatively short-noded fruiting branches 8 to 10 inches in length, is less than 3 feet in height, and has a storm-resistant boll (Fig. 20-7). The locks of a storm-resistant-type

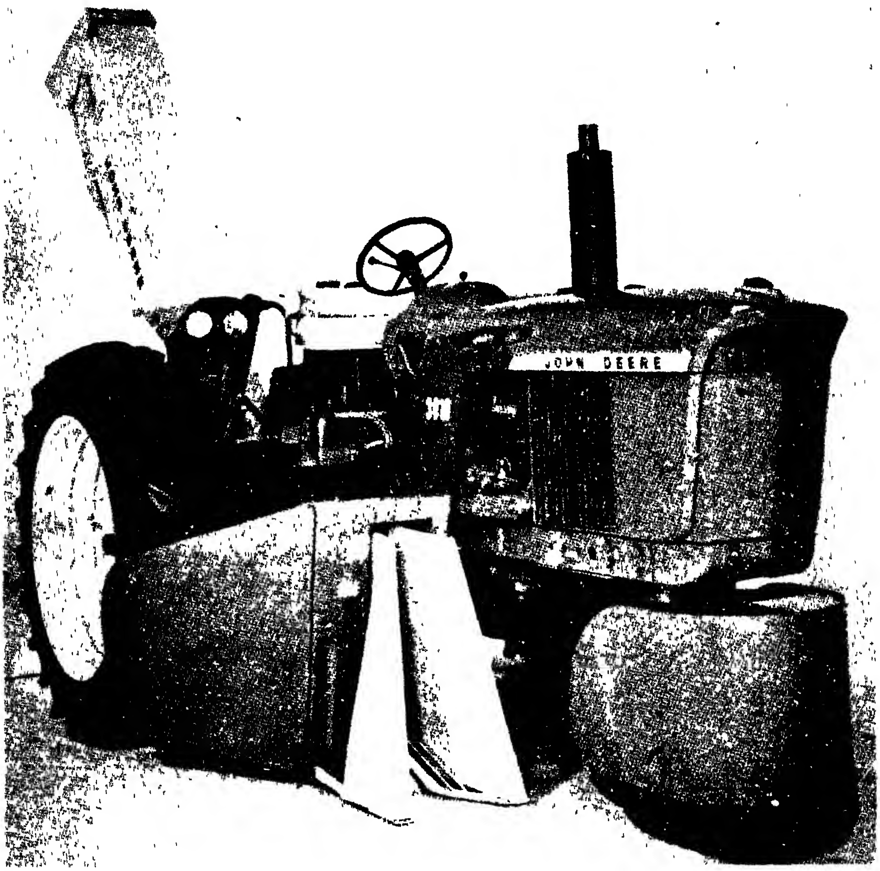

Fig. 20-2. Two-row tractor-mounted cotton stripper equipped with fenders or shields for the tractor wheels. (*Deere & Co.*)

cotton are usually not very fluffy and are held tightly in the boll. Fluffy and loosely attached locks (Fig. 20-7) are easily caught and held between limbs and thus are pulled through the stripping space and lost.

Thickness of Plants in Row. Figure 20-8 shows that plants planted thick and closely spaced in the row are smaller in diameter, have shorter limbs borne higher off the ground, and are not so tall as plants thinly spaced in the row. The data in Table 20-1 show that the performance of the stripper

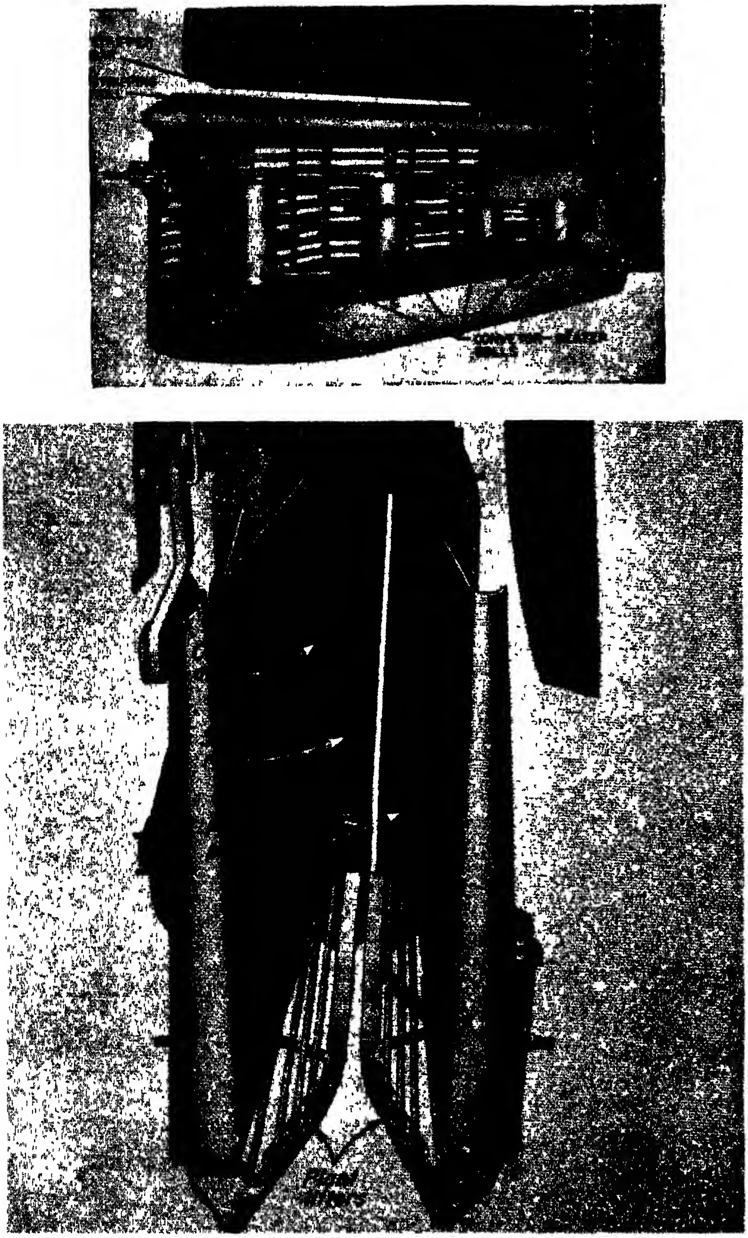

Fig. 20-3. The cotton-stripper unit at the top uses a single stripping roll and a stripper bar with a series of beater rolls to convey the cotton to the rear. Note the perforated sheet-metal bottom for the conveyor to screen out dirt and trash. The stripper unit at the bottom uses a single stripper roll and bar with auger conveyor. (*International Harvester Company, Deere & Co.*)

is better with the thickly spaced plants. Plant populations of 30,000 to 40,000 plants per acre retard plant growth sufficiently to reduce field losses materially in harvesting with a cotton stripper.

Cultural Practices. When cotton is to be mechanically stripped, the various cultivations should be made with the sweeps set flat and little soil thrown around the base of the plant. At the last cultivation, the soil

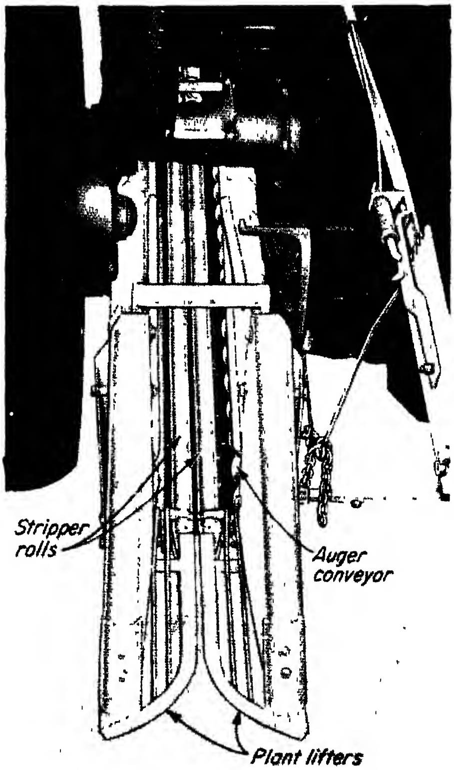

Fig. 20-4. Front view of cotton-stripper unit equipped with double steel stripping rolls and two auger conveyors. (*Allis-Chalmers Mfg. Co.*)

should be 1 or 2 inches higher at the base of the plant than in the middle. This permits winds to shift leaves and trash into the depression in the middle between the rows (Fig. 20-9). Every effort should be made to keep the field free of weeds, grass, and vines. Pieces of grass collected with the cotton are hard to remove, and if present in excessive amounts, they will reduce the quality of the cotton lint.

Pickup Fingers or Limb Lifters. The function of the fingers at the front of the machine (Figs. 20-3 and 20-4) is to slip under and lift the low

limbs and bolls and also to strip off the bolls on or near the ground. They should be set rather flat, at not over a 5- to 10-degree angle with the ground. They should be flexible enough to yield to large-stemmed plants.

Design of the Stripping Unit. The design and type of stripping unit are the most important mechanical factors influencing the performance of a cotton stripper.

When a single roll is used on one side of the plant and a stationary bar on the opposite side, the cotton must be transferred to a single conveying

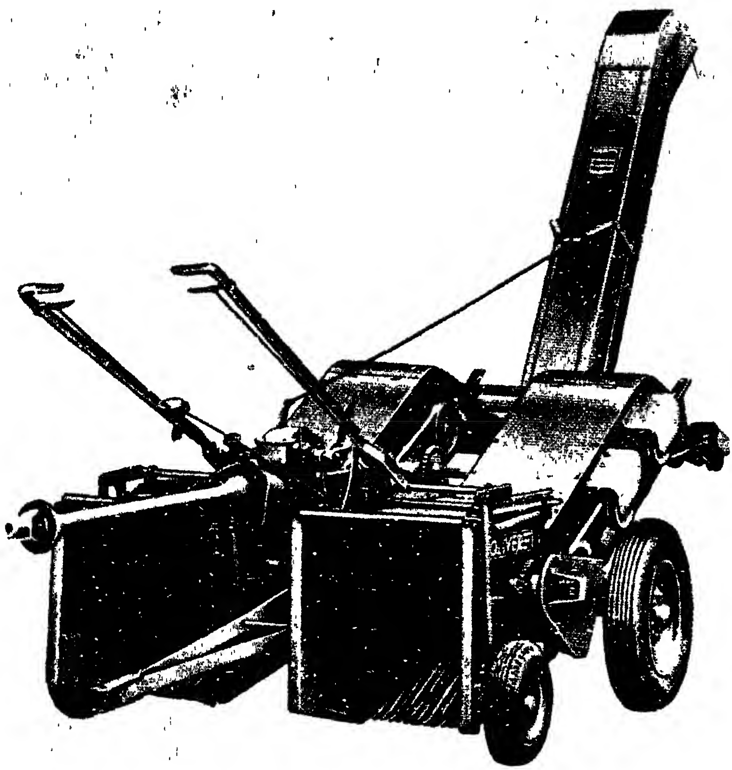

Fig. 20-5. Two-row pull-type cotton stripper equipped with long steel bar teeth to comb the cotton bolls from the plants. (*Oliver Corp.*)

channel adjacent to the roller (Fig. 20-3). The bar can be adjusted to provide a space between the roller and the bar to suit the size of plants being harvested. Figure 20-10 shows a beater located at the top of the stripping roll to clear trash.

When double steel rollers are used, a conveying channel is provided on each side of the plant (Fig. 20-4). One of the stripping rollers is

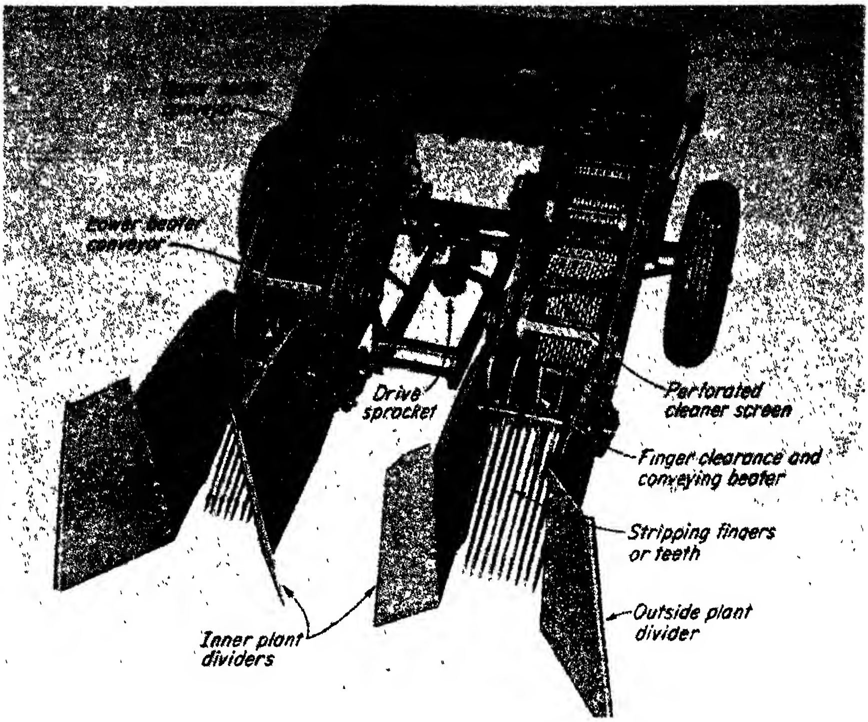

Fig. 20-6 Off-tractor view of two-row tractor-mounted cotton-stripper assembly showing stripping fingers or teeth, beater conveyors, and trash screens. (*Oliver Corp.*)

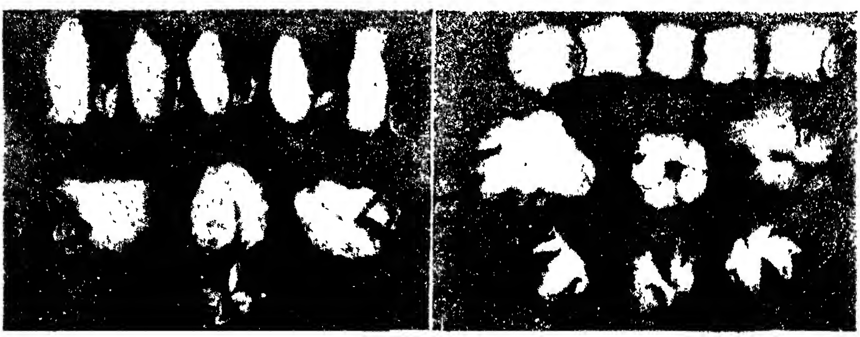

Fig. 20-7. Two types of cotton: *left,* a typical variety of cotton that is easy to pick and is lacking in storm resistance; *right,* extra-storm-resistant type of cotton that is hard to remove from the boll.

usually under spring load and can be adjusted to operate with a space between the rollers ranging from about ⅜ to ¾ inch, but it should yield enough to give a maximum space of more than 1 inch. As the sides of the revolving rolls in contact with the plants are moving upward, there is considerable pull on the plants. If the plants do not have a good root system, they will be pulled from the ground. To counteract this upward

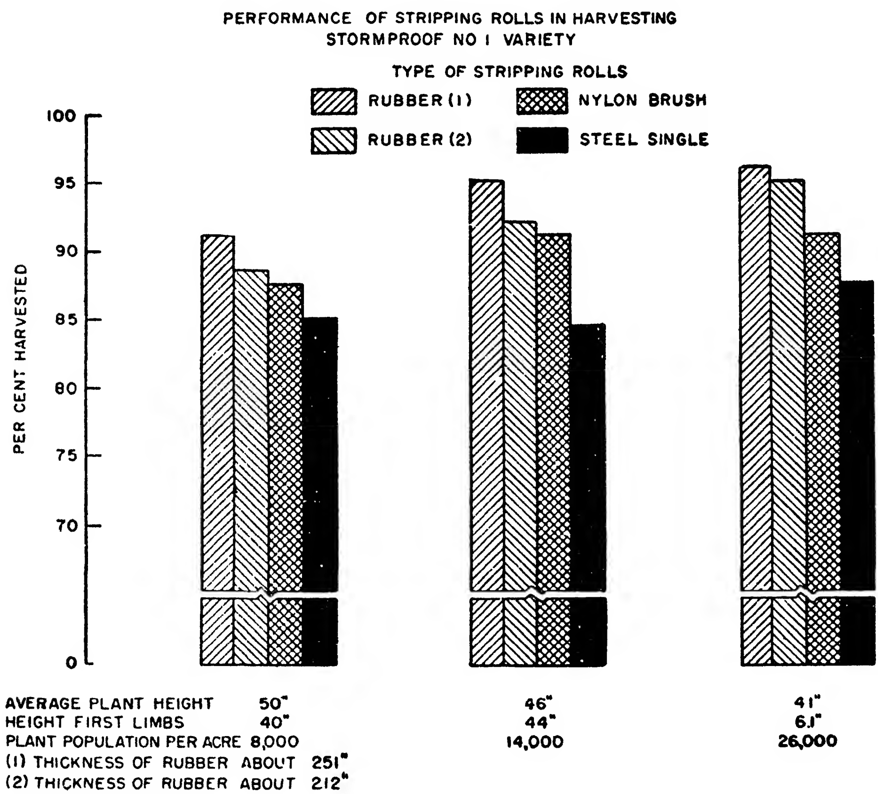

Fig. 20-8 Chart showing the effect on cotton-stripper performance where plants were thin, medium, and thick in the row. (*Texas Agricultural Experiment Station.*)

pull there are power-driven rollers that rotate counter to the stripper rolls and prevent the plants from being pulled from the ground (Fig. 20-11). These rollers are mounted under the stripping rolls.

When the stripping rollers are constructed of rows of bristles or strips of rubber, they are held rigid, but means are provided for adjusting the space between the rollers to suit plant conditions.

Generally, cotton-stripper rollers are mounted at an angle of approxi-

TABLE 20-1. PERFORMANCE OF RUBBER PADDLE, BRUSH, AND STEEL STRIPPING ROLLS IN HARVESTING TWO VARIETIES OF COTTON WITH THREE POPULATIONS OF PLANTS, BRAZOS RIVER VALLEY LABORATORY, 1952*

Type of stripper roll	Stormproof no. 1						Deltapine D-5					
	Storm loss before stripping	Cotton lost on ground by stripper	Cotton left on plant by stripper	Cotton harvested by stripper	Total yield on plant before stripping	Percentage of cotton on plant harvested by machine	Storm loss before stripping	Cotton lost on ground by stripper	Cotton left on plant by stripper	Cotton harvested by stripper	Total yield on plant before stripping	Percentage of cotton on plant harvested by machine
	Low population											
	38,550 plants per acre						11,110 plants per acre					
Rubber...	14	33	17	1,450	1,514	96.7	29	146	24	1,594	1,793	90.4
Brush.....	8	65	10	1,290	1,373	94.5	35	191	64	1,372	1,662	84.3
Steel......	8	162	48	1,254	1,472	85 6	34	304	103	993	1,434	70.9
	Medium population											
	66,910 plants per acre						19,470 plants per acre					
Rubber...	25	22	13	1,464	1,524	97 7	43	127	24	1,477	1,676	90.7
Brush.....	8	52	10	1,333	1,403	95 6	40	152	42	1,307	1,541	87.1
Steel......	13	144	31	1,150	1,338	86.8	39	302	82	1,006	1,429	72.4
	High population											
	104,670 plants per acre						70,960 plants per acre					
Rubber..	17	26	10	1,359	1,412	97 4	88	68	9	1,333	1,498	94.5
Brush.	5	47	9	1,385	1,446	96.1	81	84	26	1,163	1,354	91.4
Steel.	10	165	37	1,150	1,362	85 1	85	285	86	876	1,332	70.2

* All weights shown are pounds of cleaned seed cotton per acre.

mately 30 degrees with the ground. The rollers should be long enough so the rear end is 30 to 36 inches above the ground. This aids in preventing the tops of tall plants from bunching and overlapping at the rear of the rollers. The peripheral or surface speed of the steel rollers should be 25 to 50 per cent faster than the travel of the machine. The brush and rubber-paddle stripper rolls are operated faster than the steel rolls, and their speed may range from 400 to 800 r.p.m.

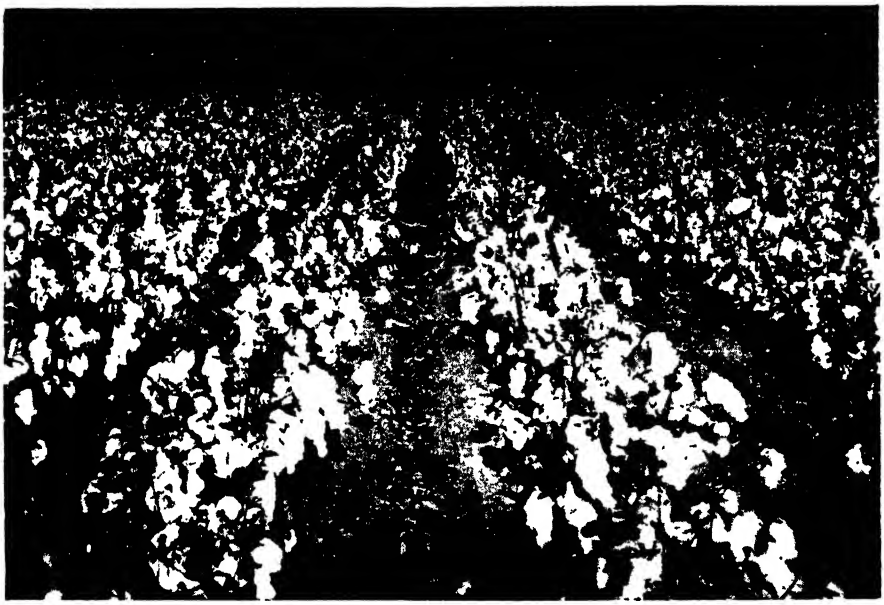

Fig. 20-9. A slight depression in the middle between the rows of cotton plants permits trash to drift and collect in the depression. (*Texas Agricultural Experiment Station.*)

The fingers on the finger-type stripper are 2 to 3 feet in length and set at an angle of about 10 or 15 degrees with the horizontal (Figs. 20-5 and 20-6).

Conveying System. There are three methods of conveying the cotton away from the stripping unit. These are (1) fingerbeater rolls, (2) augers, and (3) air.

The finger-beater rolls are used in connection with the single-roll, the double-roll, and the finger-type strippers. They are not suitable for use with the brush and rubber-paddle rolls, because the beaters throw locks of cotton against the downward-traveling outside of the roller and the locks are whipped by the doffer plate onto the ground. The finger beaters

beat a high percentage of the dirt and trash out of the cotton as it is conveyed from one beater roll to another.

The auger type of conveyor is suitable for roller-type strippers but is not used with the finger-type strippers. A tapered auger ranging from a diameter of about 4 inches at the front to about 8 inches at the rear is used on some machines, while on others the conveyor auger is of uniform size from front to rear.

Fig. 20-10. Showing power-driven trash beater to clear trash and limbs from the top of the stripping rolls. (*International Harvester Company.*)

The underhousing of all mechanical conveyors should consist of ½- by 3-inch slots of perforated sheet iron or of heavy ½-inch-mesh hardware cloth. Much dirt and trash can be screened out of the cotton through the openings in the housing under the conveyors. This is especially true where revolving beater conveyors are used. Finger-beater rolls are used to convey the cotton from the stripping fingers to the trailer elevator.

Figure 20-12 shows a fan mounted under the trailer elevator, which aids in separating green bolls and in the loading of the trailer.

It is essential that the cotton be conveyed away from the stripping unit as rapidly as possible. Air is a fast method, but the air suction also draws dirt and trash thrown over by the stripping rolls, and some of this dirt may be mixed with the cotton as it is blown into a trailer or basket.

Rate of Travel. At high rates of travel, it is difficult to steer the tractor so that the narrow space between the stripping rolls is always in line with the row of plants. If the yield is high, the volume of cotton may not be adequately handled by the conveyors. The finger-type stripper can be operated at least one tractor gear speed faster than the roll stripper because precision steering is not required.

THE COTTON PICKER

Although the cotton stripper discussed above is a type of machine for harvesting cotton, its action is so different from the mechanical cotton picker that the two types are discussed separately.

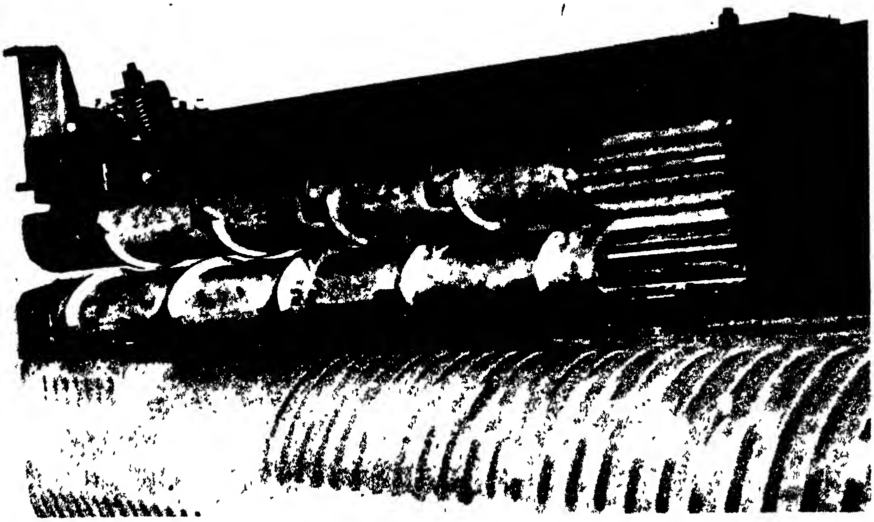

Fig. 20-11. Stalk-holding rolls are mounted under the stripping rolls to prevent plants from being pulled from the ground. (*International Harvester Company.*)

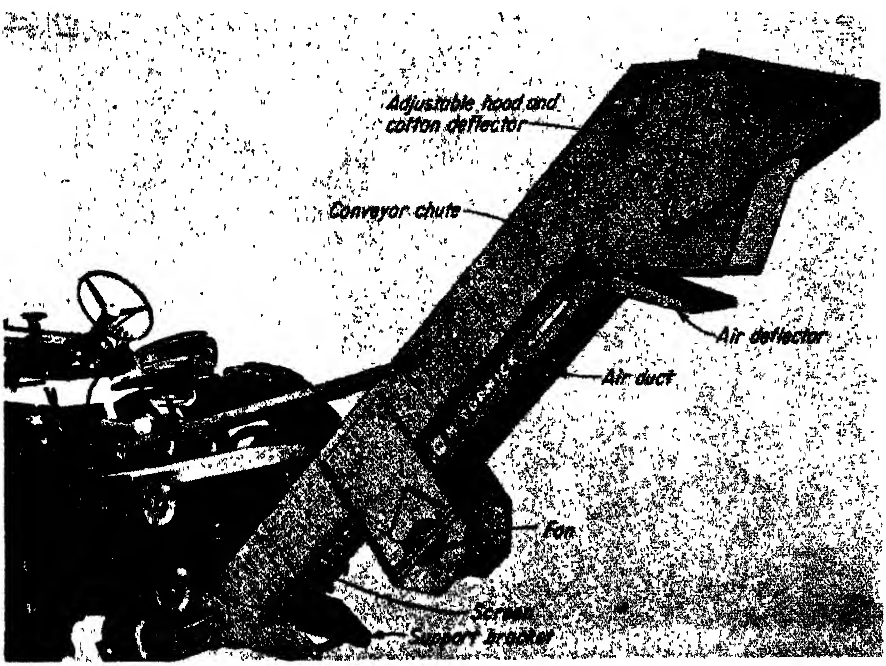

Fig. 20-12. A fan mounted under the stripper elevator aids in separating green bolls and trash from the cotton. The fan also aids in loading the rear section of the trailer. (*International Harvester Company.*)

The cotton picker performs the work of the hand picker in that only the locks of seed cotton are removed from the plant.

Types of Pickers. There are four ways of classifying cotton-picking machines:

1. By the method of mounting
2. By the number of rows harvested
3. By the height of the picking drums
4. By the type of spindle used

Cotton-picking units may be mounted on a tractor as a *tractor attachment,* or the machine may be built as a self-contained *self-propelled* unit. There are *single-row* and *two-row* machines of both the tractor-mounted and the self-propelled types (Figs. 20-13 and 20-14).

Fig. 20-13. Two-row self-propelled cotton picker dumping basket of cotton into special cotton trailer. (*Deere & Co.*)

The self-propelled picker shown in Fig. 20-13 is a high-drum picker, as it has twenty rows of spindles on each drum. It is suitable for picking

cotton from tall plants. The low-drum machine has only fourteen rows of spindles and is suitable for low-growing plants.

There are two general types of spindles. The *tapered-tooth* spindle is equipped with three or four rows of machine-cut teeth (Fig. 20-15) designed to catch and hold the cotton fiber while the complete lock is

Fig. 20-14. One-row tractor-mounted cotton picker in operation. (*International Harvester Company.*)

wrapped around the spindle. These spindles are moistened mainly to keep them free of gum, dirt, and lint.

The straight spindle may be only slightly roughened, or it may have a row of machine-cut teeth (Fig. 20-15). This type of spindle is moistened to aid the cotton fiber to adhere to the spindle so that the lock can be wrapped around the spindle as it is removed from the boll.

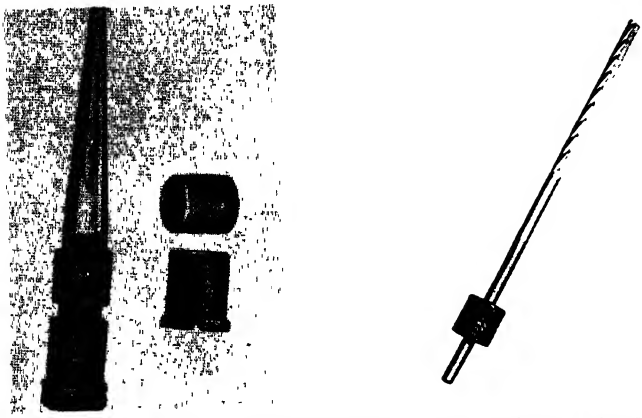

Fig. 20-15. Types of cotton-picking spindles. (*Allis-Chalmers Mfg. Co., International Harvester Company.*)

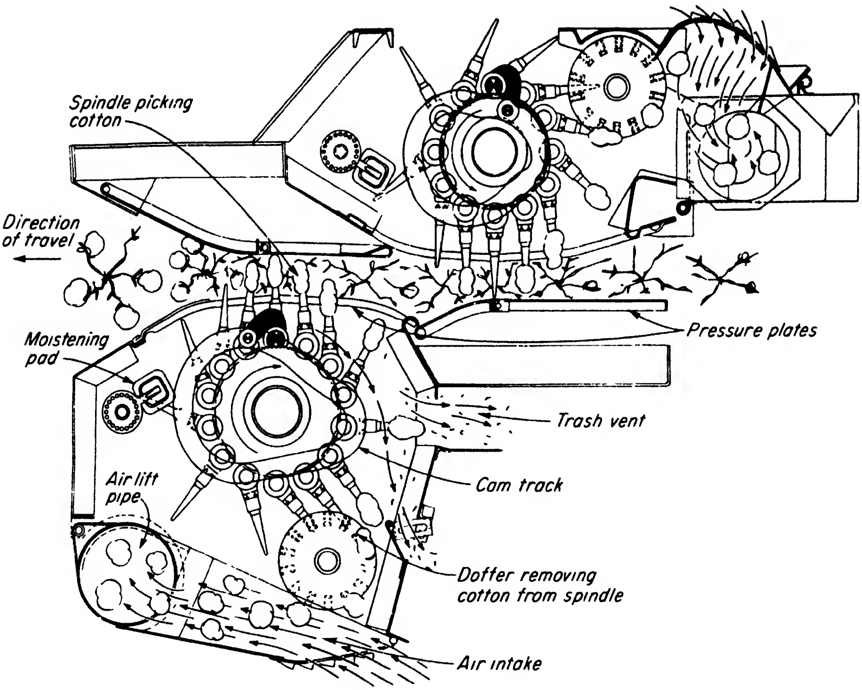

Fig. 20-16. Overhead plan view of the operational action of cotton-picker spindles picking from each side of the row. (*International Harvester Company.*)

Methods of Mounting Spindles. There are two general arrangements used for mounting and operating cotton-picker spindles, namely, the *drum* and the *chain-belt.*

The *drum spindle* arrangement is so called because the spindles are arranged in a cylindrical manner, or like a drum set on its end (Fig. 20-16). The spindles are mounted on a bar, the top end of which has a crank arm and a bearing (Fig. 20-17) that travels in a cam track. The cam-actuated picker bars swing the bars around so that the rows of

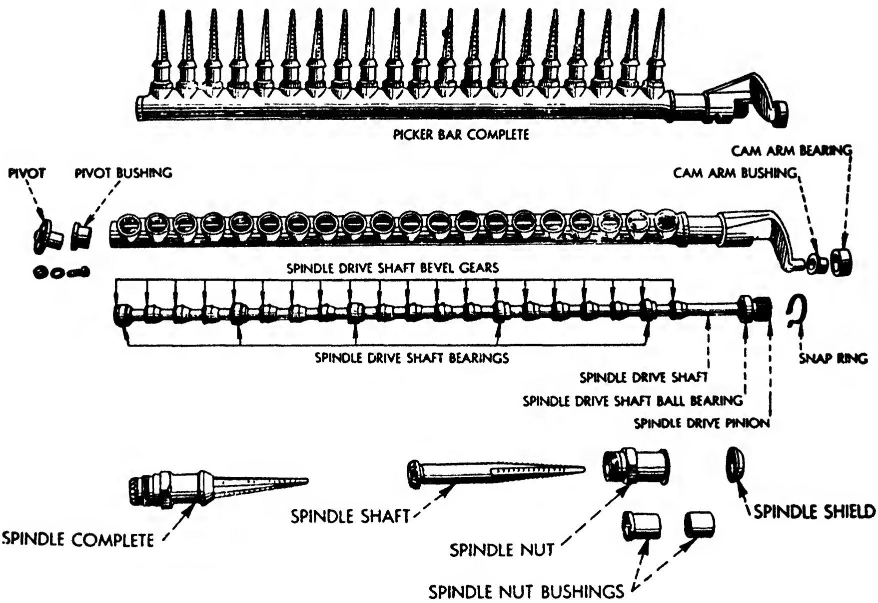

Fig. 20-17. Picker bar complete with spindles. Gearshaft removed showing drive gears, a complete picker bar, and various parts of a spindle. (*International Harvester Company.*)

spindles are about 1½ inches apart as they enter the cotton plants. As the spindles are spaced 1½ inches on the bars, the spindles are spaced 1½ inches both vertically and horizontally.

The spindle drums are operated in pairs, one drum on each side of the row, but not directly opposite, as shown in Fig. 20-16. The drum of picking bars and spindles rotates at about the same rate of speed as the tractor as it moves along the row. The spindles can be operated at two speeds to synchronize with the first and second gear speeds of the tractor. The rotation of the spindles ranges from about 2,000 r.p.m. for the first tractor gear to about 2,700 r.p.m. for the second tractor gear. The complete front drum of one machine rotates at about 60 r.p.m., and the rear drum rotates at about 79 r.p.m. Some machines are equipped with spindle

bars having twenty spindles per bar, while other machines may have only twelve or fourteen spindles per bar. These are termed *high-* and *low-*drum models. The number of spindle bars per drum ranges from twelve to sixteen; therefore, the number of spindles may range from 360 to 600 per machine.

The *chain-belt* spindle arrangement is so called because the spindle bars are attached to an endless-chain belt (Fig. 20-18). The belt consists of eighty spindle bars or slats each containing sixteen almost smooth spindles, or a total of 1,280. The belt is geared to travel at about 3 m.p.h., which is also the row travel. Generally, the spindles project into the row of plants only from one side. If two belts of spindles are arranged in tandem on opposite sides of the plant row, spindles project into the

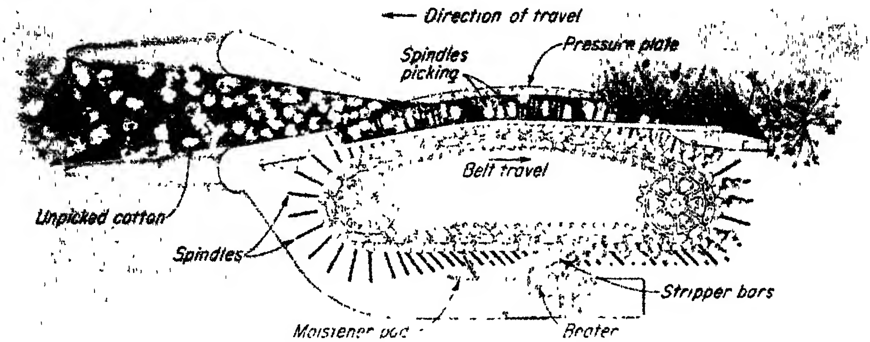

Fig. 20-18. Overhead plan view of cotton spindles mounted on a belt and picking from one side of the row. (*Allis-Chalmers Mfg. Co.*)

plants from each side of the plant row. The straight spindle is friction-driven, while the tapered-tooth spindle is gear-driven.

A moistening agent is used for all types of spindles. Tests have shown that a moistening agent such as textile oil will increase machine efficiency 2 to 3 per cent over plain water. The moistening of the spindles makes the cotton adhere to the spindle, keeps the spindle clear of gum, and aids in doffing the cotton from the spindle.

Doffing of the Cotton from Spindles. When the tapered-tooth spindles are withdrawn from the cotton plant with cotton wrapped around them, they rotate about 180 degrees and come in contact with a cylinder of rotating rubber-faced disc doffers which remove the cotton from the spindles. The cotton is dropped at the entrance of the air conveyor system (Fig. 20-16).

The straight spindles are withdrawn from the plants and carried around by the chain belt to the opposite side, where they pass between stripper bars that remove the cotton from the spindles. The cotton is conveyed away either by air or by mechanical elevators.

Elevating or Conveying Systems. All except one make of cotton picker use air for conveying the cotton from the doffing point to a tractor-mounted basket. A fan, mounted above and behind the picker units, sucks the cotton from the doffing point and blows it into the basket. The fan has a tangential by-pass which permits the cotton to pass through the fan housing. The fan blades do not come in contact with the cotton, and the seed are not damaged. At the exhaust point, the air stream is directed against a grid which deflects the cotton into the basket but allows the

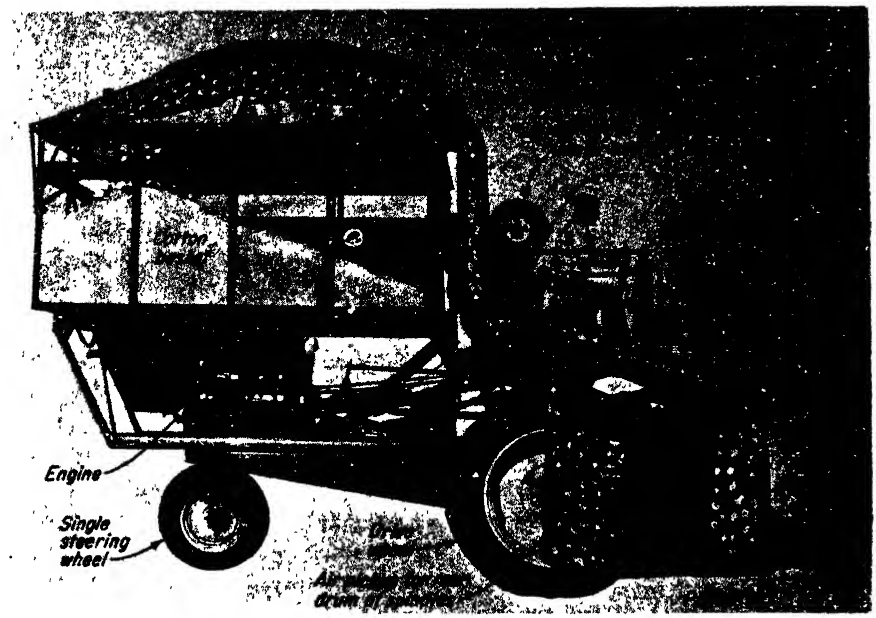

Fig. 20-19. Showing the flow of cotton from the picking spindles to the basket. (*International Harvester Company.*)

air to exhaust through the grid. Much dirt and trash are carried out with the exhausting air.

Cotton Baskets. As cotton-picking machines are usually turned almost about-face, it is not feasible to attach trailers to them. Therefore, large baskets are mounted above the picking and power units (Fig. 20-13). The capacity of the baskets ranges from about 500 to 1,200 pounds of seed cotton. When full, the baskets are usually emptied into a wide-bed trailer by tilting the basket with hydraulic power cylinders.

How a Cotton Picker Works. The features of the various units of a cotton picker have been discussed above. A better understanding of how a cotton picker works can be obtained if the flow of cotton is traced through the machine, as shown in Fig. 20-19. (1) The plants are folded into the

throat of the machine by rounded members, and low limbs and bolls lifted up by limb-lifting fingers. (2) The revolving drum or belt of rotating spindles passes under moistening pads, and the spindles are thoroughly wet. (3) The spindles then are projected in among the limbs and bolls to engage the cotton. The plants are pressed against and around the spindles by spring-loaded pressure plates. (4) The spindles rotate and come in contact with the rotating rubber doffers or the stripper-bar doffers. (5) The cotton drops into the air or mechanical conveying system which conveys the cotton to the basket. (6) Air, dirt, and trash are exhausted through grates which deflect the cotton into the basket. (7) Hydraulic cylinders tilt the basket and dump the cotton into a trailer, or the cotton is moved out of the basket into a trailer by chain raddles.

Factors Affecting the Performance of Cotton Pickers. The general classification of factors affecting the performance of mechanical cotton strippers is also applicable to mechanical cotton pickers, that is, plant characteristics, mechanical factors, cultural practices, and miscellaneous factors. The application of these factors to cotton pickers is in most cases different from the application to cotton strippers.

Plant Characteristics. Cotton-picking machines perform best when the cotton plants are of medium size. Medium-sized plants flow through the machine and permit the spindles to engage the cotton better than large plants with many long limbs. As with the stripper, the picker performs better when the lowest limbs are at least 4 inches above the ground. Cotton-picking machines require a well-opened boll with locks that are fluffy and fiber that is long enough to wrap around the spindle, be held, and be pulled from among the compressed mass of plant limbs.

The chart in Fig. 20-20 shows the performance of a mechanical cotton picker in picking several varieties of cotton having different plant, boll, and fiber characteristics. The compact-lock short-staple Hi-Bred variety gave the poorest machine performance. The locks were so compact and the fiber so short that the spindles could not hold the cotton, and much of it was dropped on the ground.

Defoliation. The collection of green-leaf particles by mechanical cotton harvesters has been the cause of the loss in quality and grade of mechanically harvested cotton ever since the machines were in the experimental and development stage.[1]

In an attempt to reduce the green leaf in mechanically harvested cotton in the early thirties, the author tested a type of cotton that had deep lobed leaves which reduced the density of the foliage.[2]

[1] Charles A. Bennett, The Relation of Mechanical Harvesting to the Production of High-grade Cotton, *Agr. Engin.*, 19(9):386–388, 1938

[2] H. P. Smith, Progress in Mechanical Harvesting of Cotton, *Agr. Engin.*, 19(9): 389–391, 1938.

Many attempts were made to develop mechanical devices to remove green-leaf particles from mechanically harvested cotton. These were not satisfactory, largely because of the fine pubescent hairs on the leaf particles that caught and hung to the cotton fiber. Dry-leaf particles were easier to remove, as the hairs became brittle and broke to release the leaf particles.

Weed-killing chemicals were tried, but they were not satisfactory because the foliage was killed quickly. This did not give the plant suf-

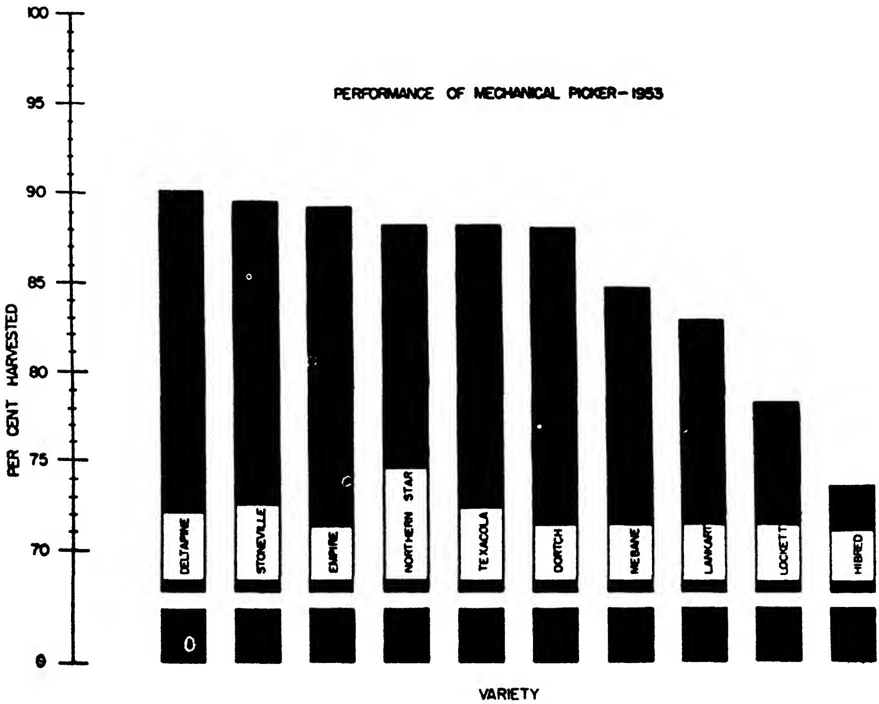

Fig. 20-20. Chart showing the effect of variety of cotton on the performance of a cotton picker. (*Texas Agricultural Experiment Station.*)

ficient time to form abscissa cells between the limb and the leaf stem and cause the leaf to fall from the plant. Then, too, excessive amounts of dry-leaf particles were collected by the mechanical harvester. In some areas this type of chemical is used as a desiccant before stripping.

The first step toward a successful chemical defoliant was made by a farmer who was applying calcium cyanamid dust as a fertilizer. Some of the dust drifted onto some cotton plants. The farmer observed that the leaves of these plants dropped off in two or three days. Cyanamid dust was used extensively until other chemicals were developed.

Now the chemical defoliation of cotton fields is generally a preharvest operation, some times even for hand harvesting.

Liquid and dust chemical defoliants can be applied by either ground or aircraft equipment as discussed in Chap. 14.

Bolls of cotton less than 36 days old at the time of defoliation may suffer loss in weight of fiber and seed and in quality of products. The early-set bottom bolls mature and open before the late-set top bolls are 36 days old. A delay in harvesting the early open cotton will result in atmospheric damage to the exposed cotton fiber.

Bottom Defoliation. Early mechanical picking of these bottom bolls without collecting many green-leaf particles can be done if the bottom part of the cotton plants are defoliated. Liquid defoliants are applied with high-clearance ground sprayers having long drops with the sprayer nozzles low enough to spray only the bottom part of the plant. The picking spindles must operate in the defoliated area of the plant. If a high-drum twenty-spindle machine is used, only the bottom twelve or fourteen rows of spindles can be used. The top eight to six rows must be removed.

Mechanical Factors. The performance of a cotton picker is greatly affected by the care taken in keeping it properly adjusted and operated. The right amount of water must be kept flowing to the moistener pads to keep the spindles moist and clean. The pressure plates must be adjusted to suit plant conditions. The doffers must be carefully adjusted to the spindles to remove the cotton properly. The condition of the spindles, both tooth and smooth, must be frequently checked. Worn-out and damaged spindles should be replaced. The elevating systems should be carefully watched to prevent plugging, stoppages, and loss of cotton. Figure 20-14 shows a cotton picker doing a good harvest job.

Cultural Practices. A slight elevation of the soil at the base of the plants and weed-free fields are as essential for good picker performance as for stripper performance. The row spacing should suit the multiple-row machines. Fairly thick and uniformly spaced plants aid the performance of the mechanical cotton picker as shown in Table 20-2.

Cotton-salvaging Machine. The data in Table 20-2 and the chart in Fig. 20-20 show that the amount of cotton either left by the mechanical picker on the plant or dropped on the ground varies with the variety of cotton. Some of the cotton on the ground may be the result of natural shedding, and some blown out by winds. Under some conditions the amount of cotton on the ground after the mechanical harvester has been used may be sufficient to justify salvaging.

One machine uses a series of slitted belts that are run in contact with the ground to pick up loose cotton lying on the ground. Figure 20-21 shows how the slits in the belt open and close as the belt passes around

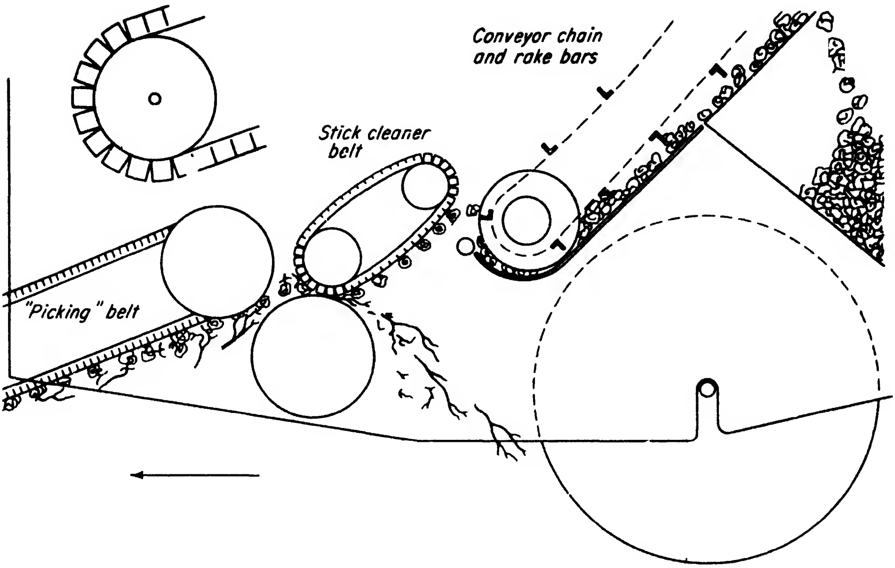

Fig. 20-21 Showing how burs and sticks are removed from cotton picked off the ground by a salvaging machine. The inset shows how the slits in a thick belt open as it passes around a pulley. As the slits close while in contact with the ground, any cotton will be pinched in the slits and picked up (*Garland Sales Co.*)

TABLE 20-2. PERFORMANCE OF MECHANICAL COTTON PICKER IN HARVESTING TEN VARIETIES OF COTTON, BRAZOS RIVER FIELD LABORATORY, 1952*

Variety	Number of plants per acre	Storm loss before machine picking	Cotton lost by picker		Yield on plants before picking	Cotton harvested by machine	Percentage of cotton on plant harvested by picker
			On ground	On plant			
Deltapine D-5	28,880	32	36	77	1,034	921	89.1
Empire	36,590	7	18	57	1,153	1,078	93.5
Texacala	25,483	11	40	129	1,051	882	83.9
Northern Star	23,653	10	25	70	859	764	88.9
Lockett 140	41,295	39	51	90	892	751	84.2
Dortch	29,795	88	46	69	951	836	87 9
Lankart 57...	21,170	3	26	112	791	653	82.6
Mebane. . . .	35,806	17	44	72	815	699	85 8
Hi-Bred. .	29,534	101	124	124	790	542	68.6
Stoneville. .	16,988	114	65	41	1,054	948	89.9

* All weights shown are pounds of cleaned seed cotton per acre.

SOURCE. H. P. Smith and E. C. Brown, Mechanical Harvesting of Cotton, mimeograph, *Tex. Agr. Expt. Prog. Rpt.* 1527, 1953.

the pulley. The loose cotton is caught in the closing slits and held until the slits open and release the cotton as the belt passes around the upper pulley. Most of the foreign matter picked up with the cotton is removed as the cotton is passed to a second belt.

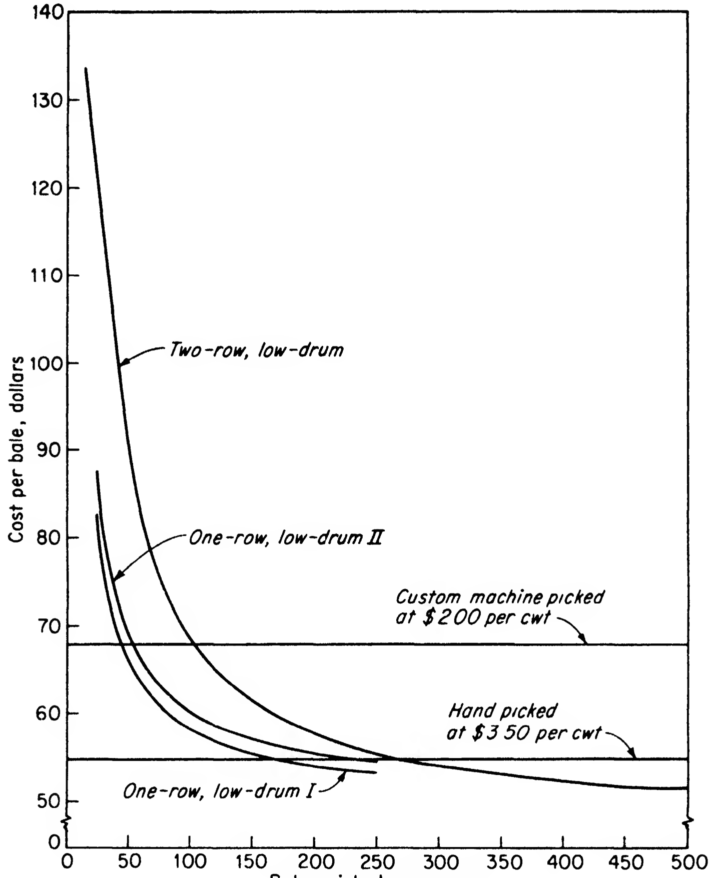

Fig. 20-22. Per bale harvesting cost on cotton yielding one bale per acre for two one-row low-drum machines, one two-row machine, custom machine harvest, and hand picking. (*Arkansas Agricultural Experiment Station Bul.* 122, 1960.)

There are several other types of cotton-salvaging devices. One uses a series of carding belts to pick the cotton off the ground. Others use rubber finger-wheels and brushes to sweep and flip loose locks of cotton onto the picking spindles.

Miscellaneous Factors. A well-trained and careful operator is essential to obtain the best performance from a cotton-picking machine. The oper-

ator should carefully study the instructions in the operator's manual and learn the functions and adjustments of the various parts of the machine. Custom outfits generally have a trained serviceman to take care of machine adjustments, but the operator must handle the machine properly to obtain the best performance.

COST OF HARVESTING COTTON

It requires 1,200 to 1,500 pounds of hand-picked seed cotton to produce a 500-pound bale of lint cotton; the average price paid for picking of 100 pounds of seed cotton will vary with the price of lint cotton and the general economic condition of the country. In times of depression and low values, the price may be 50 to 60 cents per 100 pounds of seed cotton, while in years of peak prices the price may be $1.50 to $3 per 100 pounds. Therefore, the differential saving in harvesting costs between hand and machine methods will vary. An average of 2,200 pounds of hand-snapped and machine-stripped cotton is required to produce a 500-pound bale of lint cotton. The amount required will be influenced by the variety, the field conditions, and the type of machine used. At $1.50 per hundred for harvesting by hand-snapping, the cost per bale will be $27.75. If hauling and ginning charges are included, the cost is approximately $39. If all costs and charges are considered, the average cost to machine-strip a bale is approximately $17. This gives a saving of around $22 per bale in favor of machine-stripping. Similar savings are noted when the hand-picking and machine-picking methods are compared. The number of 500-pound bales of lint cotton harvested with any type of mechanical harvester will vary directly with the yield, or the amount of cotton available for the machine to harvest. The cost, of course, will vary correspondingly. The graph in Fig. 20-22 shows the comparative costs per bale for one-row and two-row cotton pickers as affected by the number of bales harvested. The over-all cost per bale decreased as the number of bales harvested increased.

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QUESTIONS AND PROBLEMS

1. Explain why mechanical cotton harvesting machines were not adopted by cotton farmers before 1943.
2. Explain the difference in principle of operation between a cotton-stripping and a cotton-picking machine.
3. Explain the differences between the different types of cotton strippers.
4. Discuss the various factors that may affect performance of a cotton stripper.
5. Explain the different methods of classifying cotton picking machines.
6. Explain the structural difference in a tapered and straight spindle, (*a*) the method of mounting, (*b*) the method of doffing, and (*c*) the method of spindle drive.
7. Explain the need for moistening the spindles of cotton pickers.
8. Discuss the factors that affect the performance of a cotton picker.
9. What is meant by defoliation?
10. Why is bottom defoliation practiced?
11. Describe the action of the slitted belt-type cotton-salvaging machine.

ROOT HARVESTING EQUIPMENT

21

Several field crops, such as potatoes, beets, peanuts, and sweet potatoes, form tubers or roots below the surface of the ground. Specially designed machines are required to dig and separate them from the soil.

POTATO HARVESTERS

In general, potato harvesters (diggers) can be classed as one-row and two-row tractor-drawn machines. The two-row machines can be further divided into three types, namely, the *two-unit* or *separate apron;* the *two-row, open throat, connected apron;* and the *combination digger-cleaner-sacker*, or *loader*. The last can be called a potato combine.

One-row Harvester. The one-row potato harvester is drawn behind the tractor, but the elevating and shaking apron is power-take-off driven (Fig. 21-1). A long power shaft extends from the power take-off to an enclosed gearbox on the harvester. This gearbox usually consists of a three-speed transmission which permits the elevator to be operated at speeds suited to the field condition.

Several types of digging blades are available. The blade is run deep enough to scoop up the buried potatoes. The complete mass of soil and potatoes is delivered to a traveling elevator chain which is agitated up and down by elongated sprockets on each side of the chain (Fig. 21-2). This agitation shifts loose soil through the links of the chain, which are usually offset alternately; that is, one link is high, while the next link is set low. The chain belt may be constructed as a continuous belt from front to rear, or it may be divided into two sections (Fig. 21-2).

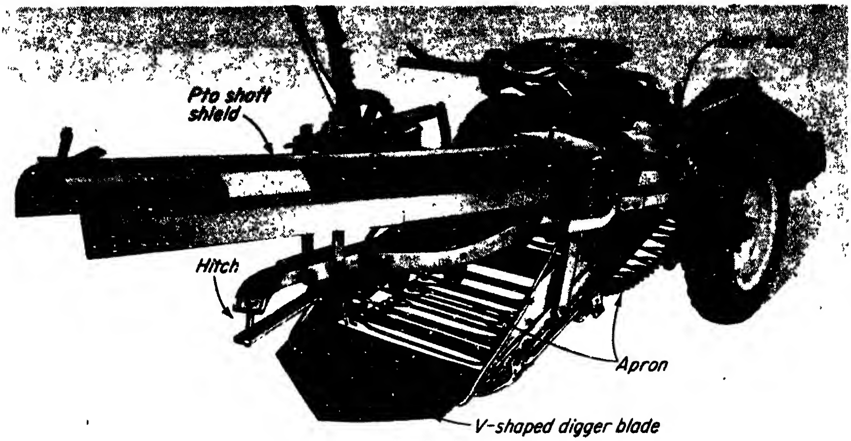

Fig. 21-1. One-row trailing power-take-off-driven potato digger. (*International Harvester Company.*)

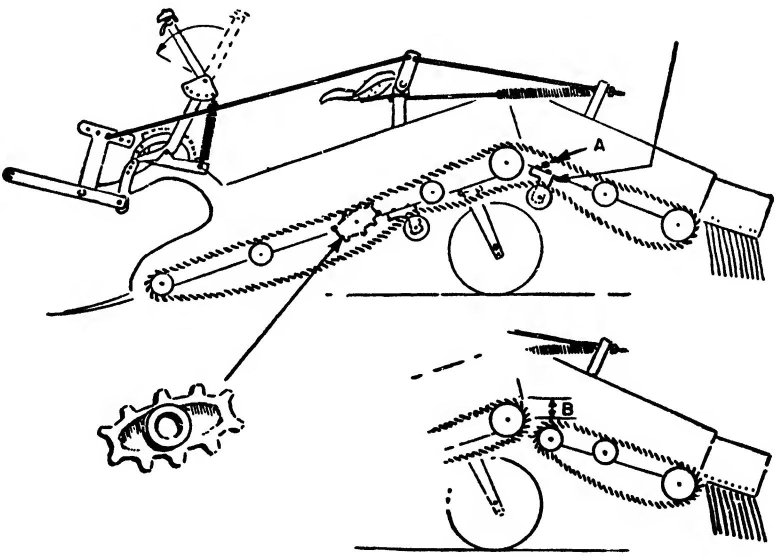

Fig. 21-2. Types of chain-belt elevator aprons used on potato harvesters: *A*, the continuous apron; *B*, the divided apron. The inset shows the elliptical sprocket for agitating the belt.

Martin and Humphrey of Idaho found that rubber-covered links and rollers reduced the percentage of bruised potatoes.

Two-row Harvesters. The two-row potato harvester usually consists, in a way, of two single-row units mounted on a long, heavy axle with a suitable frame supported on wheels (Fig. 21-3). The power drive shaft

is located between the units. Each unit is driven by a cross-shaft. Levers permit the adjustment for depth of each unit separately. Deflectors at the rear of the elevator apron throw the potatoes from the two rows fairly close together, which aids in picking them up (Fig. 21-4). Levers are available for adjusting the depth of penetration of the digging blade and for lifting the blade above the bed. Some machines are equipped with remote-control hydraulic cylinders to lift the blades which are attached to the framework of the machine.

The *connected-apron two-row harvester* has a wide blade that extends across two beds and the row between them (Fig. 21-5). The two beds and middle are cut and fed onto the elevators. This type of machine is

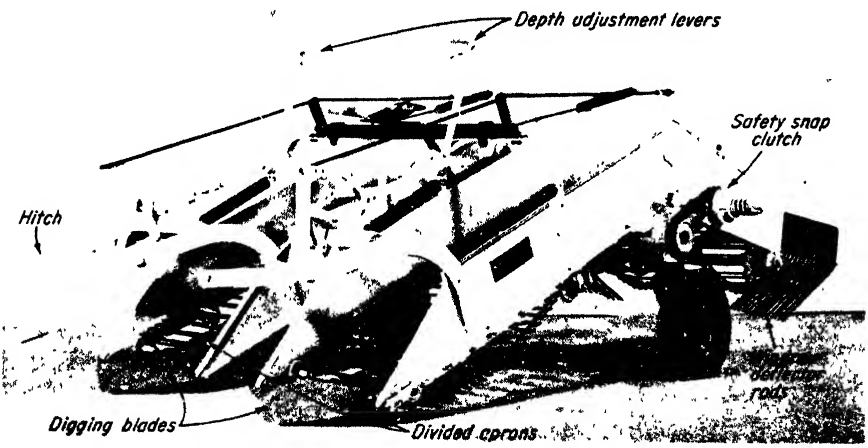

Fig. 21-3. Side view of two-row power-take-off-driven potato digger consisting of two units mounted together. The aprons operate in separate chutes. (*Champion Corp.*)

most suitable for harvesting level beds. The potatoes from the two rows are dropped out of the machine bunched together.

Some potato growers use a chemical to kill the tops or power-operated beaters to dispose of the vines and weeds before operating the potato harvester.

Potato Combine. The machine shown in Figs. 21-6 and 21-7 is drawn along the row by a tractor, but the elevators and carrier belts are operated by an auxiliary engine mounted on top of the framework or by the tractor power take-off. The potatoes can be delivered in bulk to a truck or trailer driven along beside the machine. Machines that dig and sack or load the potatoes in a single operation are termed *potato combines.*

Cost of Harvesting Potatoes. Schrumpf of Maine found that the cost per barrel of harvesting potatoes decreased as the rate of digging increased. The cost averaged 35, 30, and 26 cents per barrel when the

Fig. 21-4. Rear view of two-row power-take-off-driven potato digger in operation. (*Deere & Co.*)

harvesting rate was 350, 350 to 649, and 650 or more barrels per day, respectively (Table 21-1, Fig. 21-8).

SWEET-POTATO HARVESTERS

The sweet potato has long, tangled vines which make harvesting difficult. It is necessary that these vines be cut before any machine can be used to uproot the potatoes. A number of vine-cutting devices have been tried with varied results. The South Carolina Agricultural Experiment Station designed a vine cutter consisting of two blades spaced about 5 inches apart on the underside of a spring-loaded metal slide. The spring holds the slide down against the beds with a pressure force of about 100

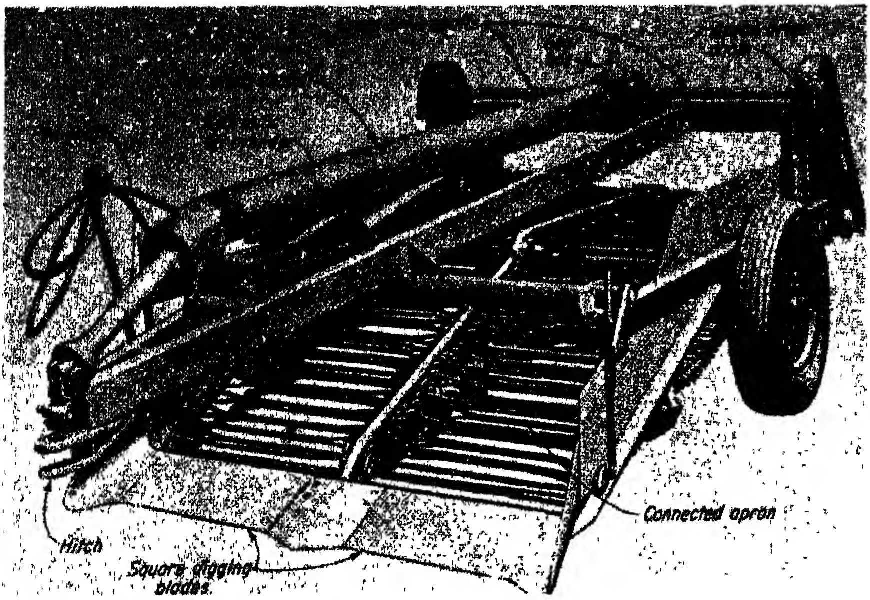

Fig. 21-5. Front view of two-row power-take-off-driven open-thıoat oı twin-apron potato digger. (*Champion Corp.*)

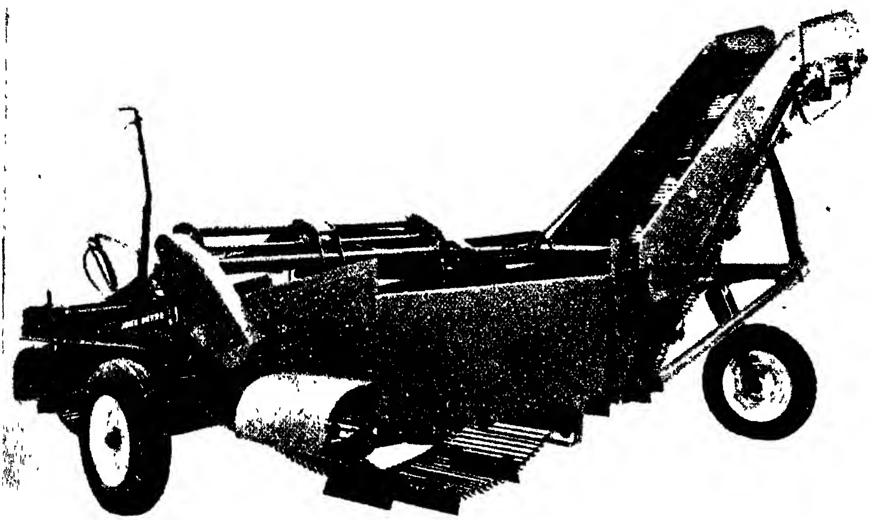

Fig. 21-6. Two-row power-take-off-driven potato digger. It is equipped with a stone picker attachment. (*Deere & Co.*)

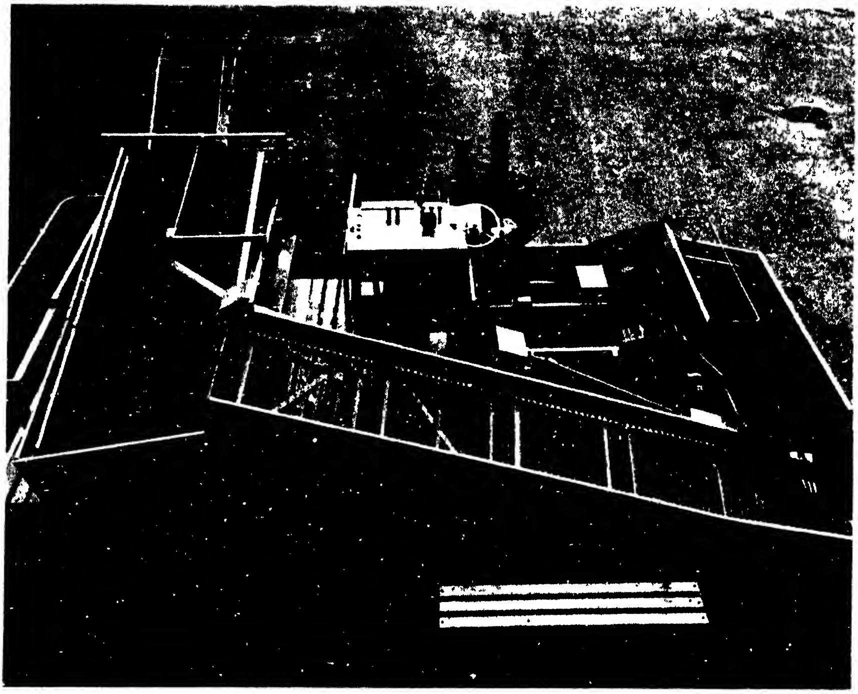

Fig. 21-7. Potato combine. (*Champion Corp.*)

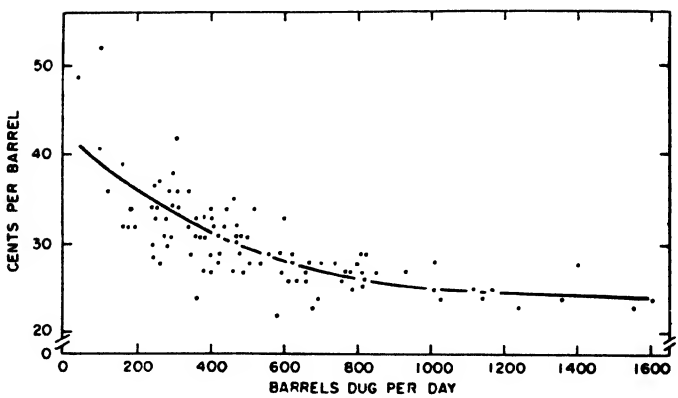

Fig. 21-8. Chart showing the cost of digging in relation to the rate of digging potatoes. (*Maine Agricultural Experiment Station.*)

TABLE 21-1. COST OF DIGGING AND PUTTING POTATOES INTO STORAGE BY VARIOUS HARVESTING SYSTEMS, AROOSTOOK COUNTY, 1961

Cost items	Conventional 2-row digger with barrels	2-row self-propelled harvester with bulk bodies	2-row tractor drawn harvester with bulk bodies	1-row tractor drawn harvesters with barrels	bulk bodies
Number of machines	2	3	2	5	2
Av. acres harvested	83	102	110	50	51
Av. barrels harvested	13,104	17,120	17,950	7,375	8,898
	Fixed costs,[a] dollars per barrel				
Depreciation	0 01	0 07	0 06	0.07	0 08
Insurance, taxes, and interest[b]	0 01	0 03	0 02	0 02	0 03
Total	0 02	0 10	0 08	0 09	0 11
	Variable costs,[c] dollars per barrel				
Labor:					
Harvesting	0 03	0 10	0 15	0 16	0 13
Picking	0 26				..
Hauling and storing	0 09	0 05	0 07	0 09	0 07
Miscellaneous	0 01	0 01	0 00[d]	0 01	0 01
Truck[e]	0 02	0 01	0 01	0 03	0 01
Tractor[f]	0 01	0 02	0 01	0 03	0.04
Repairs	0.01	0 04	0 02	0.03	0 05
Baskets and barrels	0 02			0 02	. .
Total	0 45	0 23	0 26	0 37	0.31
All costs	0 47	0 33	0 34	0.46	0.42

[a] Exclusive of investment in tractor, truck, and auto.

[b] When not given, insurance assumed to be 40 cents per $100 valuation based on 55 per cent of average value; taxes assumed to be $3.50 per $100 valuation based on 50 per cent of average value.

[c] Includes auto and fuel for auxillary motor.

[d] Less than 0.005.

[e] Fixed rate applied to truck use: large, $1.70 per hour or 17 cents per mile; small trucks and autos, 85 cents per hour or 8.5 cents per mile.

[f] Fixed rate applied to tractor use: 3-plow, $1.24 per hour; 2-plow, 85 cents per hour.

SOURCE: Winston E. Pullen, New Potato Harvesters Cut Digging Costs, Department of Agriculture, Business, and Economics, University of Maine, ABE Rept. No. 105, 1962.

pounds. The slide is attached to a frame on the tractor so that the vines are cut just ahead of a digger mounted on the rear of the tractor.

Irish-potato harvesters will lift and separate the sweet potatoes from the soil and leave them on top of the ground but, in doing so, cause excessive bruising, which makes this type of machine unsatisfactory for harvesting sweet potatoes.

Research workers in Texas, Louisiana, and South Carolina have worked on the development of diggers especially suited for the harvesting of sweet potatoes. The digger shown in Fig. 21-9 exposed about 93 per cent of the potatoes with average bruising damage. The South Carolina machine consists essentially of a middlebuster and an arrangement of shifting

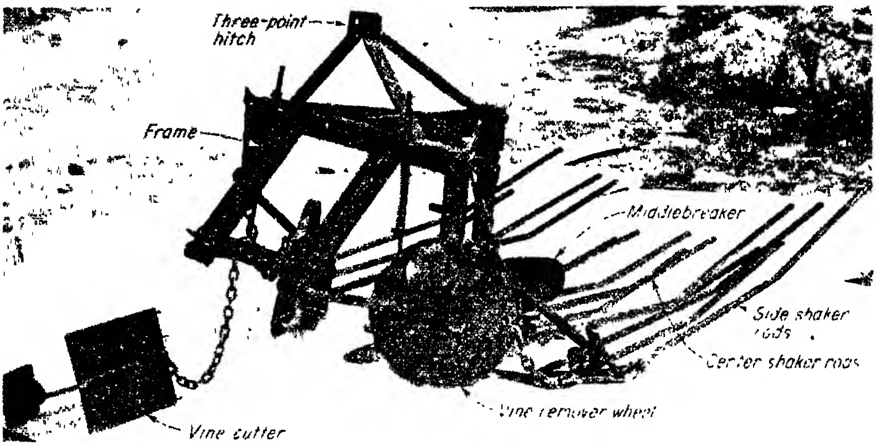

Fig. 21-9. Tractor-mounted sweet-potato digger (*DARF Corp.*)

rods which sift the buried sweet potatoes to the surface where they are visible to the pickers. The middlebuster is specially made with a wide point and short wings and is mounted on a high-clearance frame. One gang of sifting rods is mounted behind the middlebuster by means of pivots which allow the rods to slide on the ground. The two side-rod assemblies utilize two bearings each, which permit them to slide on top of the ground in a horizontal position regardless of plow depth. Most of the furrow of soil and sweet potatoes plowed out by the middlebuster falls on top of the side rods, and most of the sifting is done by the side rods.

Disks mounted in front of the side-rod assemblies push the cut vines to the middle. The vines are covered with soil, so the side rods slide over and above the vines. The rods behind and to each side of the middle-breaker bottom push the potatoes to the surface.

SUGAR–BEET HARVESTERS

Sugar beets are grown under a wide variety of soil and climatic conditions. These factors cause the roots and tops to develop differently in different areas, making it difficult to adapt machines to the varied types of growth, soil, and weed conditions and to meet the desires of the growers.

Patents were granted on mechanical sugar-beet harvesters as early as 1898. Machines were used to some extent in the 1930s, but it took the

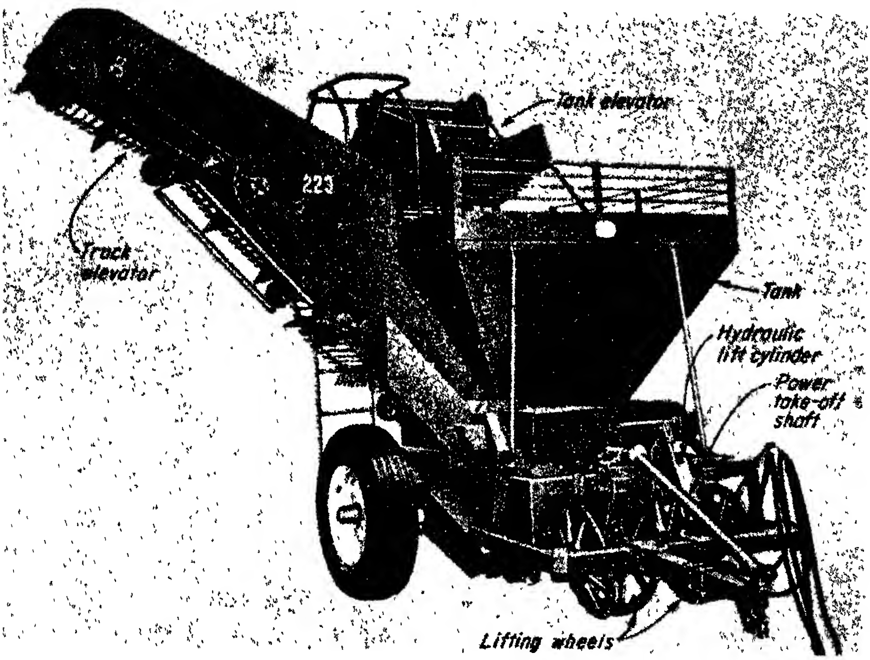

Fig. 21-10. Trailing two-row beet digger equipped with elevator to load beets into tank. The tank has a power-driven unloader belt. (*Deere & Co.*)

scarcity of labor during the Second World War to bring farmers to accept and use the machines available. Large-scale use of beet harvesters began in 1943, and by 1953 probably 80 per cent of the beets grown were mechanically harvested. In 1962 almost all of the sugar beet crop was mechanically harvested.

Beet harvesters may be either tractor-mounted or trailed behind the tractor (Fig. 21-10). The mechanism in both types is power-take-off driven. One- two- and three-row sizes are available. The harvesters are operated from 2¼ to 5 m.p.h. and can harvest from 25 to 30 acres per day.

Topping the Beets. Beet leaves can be removed by letting herds of sheep graze them off, by beating them off with rotary beaters, or by topping devices. Most beets are topped before they are lifted from the ground. Figure 21-11 shows a typical topping device mounted on the tractor. It consists of a power-driven notched-edged disk set flat to scoop off the beets slightly below or above the lowest leaf scar, depending on the size of the beets. The position of the topping disk is gaged by a *finder*, which may be a sliding shoe, a power-driven wheel roller, or belt. The pressure spring should not exert a force in excess of 60 pounds. The tops are thrown to one side by a power-driven *top flinger*. Beets can be

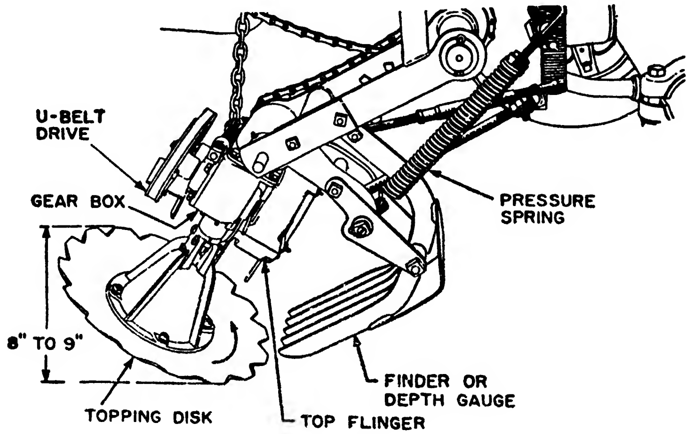

Fig. 21-11. Enlarged view of beet topper.

topped before the digger is operated by tractor-mounted scalping knives. The machine shown in Fig. 21-12 tops the beets after they are lifted from the ground.

Lifting the Beets. The lifting unit is mounted just back of the topper. The soil can be loosened around the beets by two large, notched rolling colters set a few inches apart and at an angle.

There are four types of beet lifters. The oldest and simplest consists of two helical-shaped blades that straddle the row. The second type consists of two spade- or solid-rim-type wheels tilted or angled so the rim closes under and lifts the beets from the soil (Fig. 21-10). The third method of lifting beets consists of a large spiked wheel some 30 inches in diameter (Fig. 21-12). The spikes are forced into the roots as the wheel rolls over them. As the wheel turns, the roots are lifted from the soil. The fourth method of removing beet roots from the soil consists of a pair of inclined spring-loaded belts that grasp the tops and lift them as

the belts move up the incline. The soil is loosened around the roots by a pair of digger blades.

The Cleaning Mechanism. The soil that is lifted with the beet roots is removed as the beets pass over several rows of rotating and overlapping star kicker wheels by some types of beet harvesters (Fig. 21-13). The soil

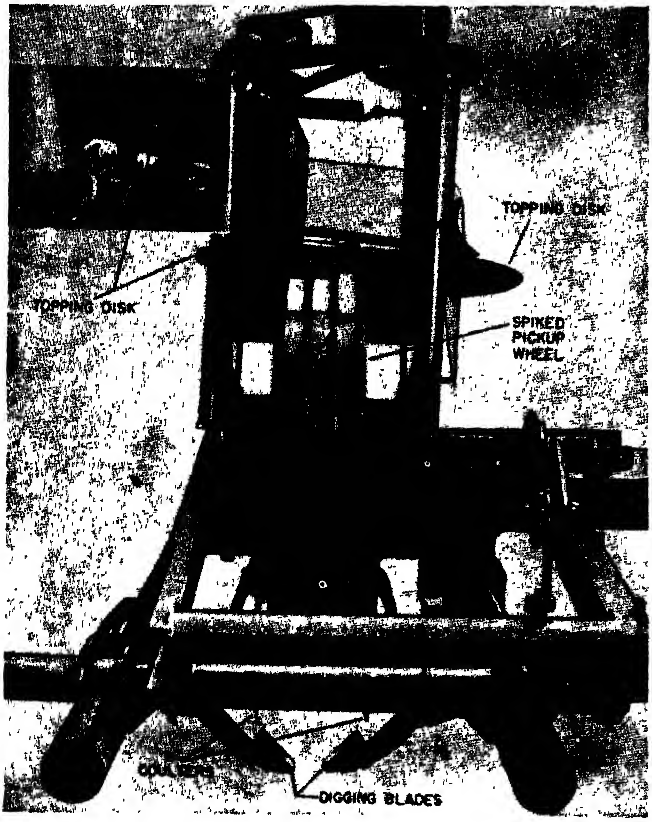

Fig. 21-12. Spike-studded wheel to lift beets out of the soil and carry them under topping device above the wheel. (*Blackwelder Mfg. Co.*)

drops out between the star wheels, but the beets are flipped from one row of wheels to another until they are delivered to the elevator.

Beet Combines. Some machines are provided with a sorting belt so that rocks and large, hard clods of dirt can be picked out manually.

Some beet harvesters have elevators that dump the beets directly into a truck box, while others deposit the beets in a tank on the machine. When the tank is filled, it is unloaded by a chain flight elevator (Fig. 21-10). This type of beet harvester can be termed a *beet combine.*

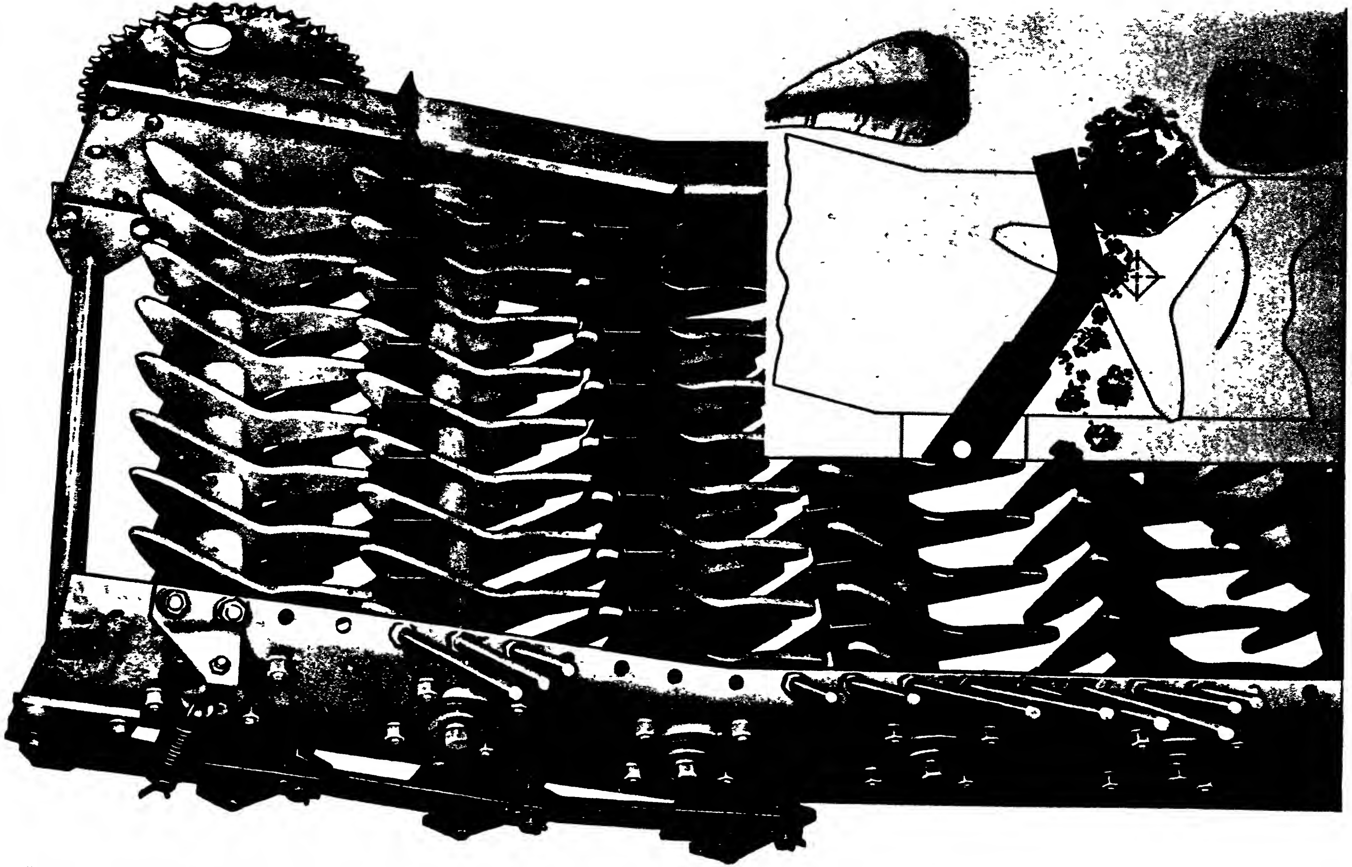

Fig. 21-13. Showing how a rotating star kicker wheel separates the soil from the beets. (*International Harvester Company.*)

PEANUT HARVESTING

The harvesting of peanuts is generally a three-stage operation: (1) the tap root is cut, and the soil loosened around the peanuts; (2) the vines and nuts are lifted from the soil, passed over a shaker to shake off loose soil, and collected in windrows; and (3) the windrows of peanuts and vines are picked up and passed through a picker or thresher to separate the nuts from the vines.

Stages 1 and 2 are usually done as a single operation, as equipment to dig and shake the vines is operated by the same tractor. The vines are left in the windrow from 3 to 10 days before stage 3, or threshing, is done. Peanuts have been dug and threshed in a single operation, but it required longer to dry the nuts and the quality was below standard.

Peanut Diggers. The peanut plant has a central tap root. Some varieties have vines or runners radiating out 8 to 12 inches from the tap root, and there may be nuts under the entire plant. Other varieties do not have runner vines, and the nuts are bunched on fibrous roots near the tap root.

Digging of peanuts requires a long knife set fairly flat with the cutting edge extending backward at an angle of about 30 degrees (Fig. 21-14). The knife is set to run about 2 inches deep underneath the plants to cut the tap roots and loosen the soil around the nuts. The knives for digging two rows are usually mounted centrally on the tractor. Some growers use two long-bladed cultivator half-sweeps mounted on a cultivator frame to dig peanuts. The knives and sweep blades are set so that they extend toward each other to aid in partially windrowing the vines. Rods can be attached to the knives and knife standards to aid in windrowing the vines from the two rows.

Peanut Shakers. Peanuts for combine or stationary threshing should be as free of dirt as possible. For combine threshing, four to six rows are windrowed together. The side-delivery hay rake has been extensively used to windrow and shake peanuts. This type of work is heavy for a side-delivery rake and causes excessive wear and breakage of parts. The peanut vines are tangled, and the windrow is too compact for rapid drying.

Special equipment has been developed which lifts, shakes, and places the vines in relatively light and untangled windrows. There are a number of machines available for lifting and shaking peanuts. Tests in Alabama indicate that a peanut shaker should be approximately 54 inches wide to handle runner peanuts where rows are spaced 34 to 36 inches apart. The shaker should be designed to raise or elevate the peanuts about 48 inches in order to shake and windrow the peanuts effectively. Figure 21-14 shows a two-row semimounted power-take-off-driven peanut lifter, shaker, and windrower.

Peanut Threshers and Pickers. There are generally two types of machines for separating the peanuts from the vines. They are classified according to the type of teeth used on the cylinder and are termed *threshers* and *pickers*. The thresher has the regular straight teeth similar to those used on a grain thresher, except they are spaced farther apart on the cylinder

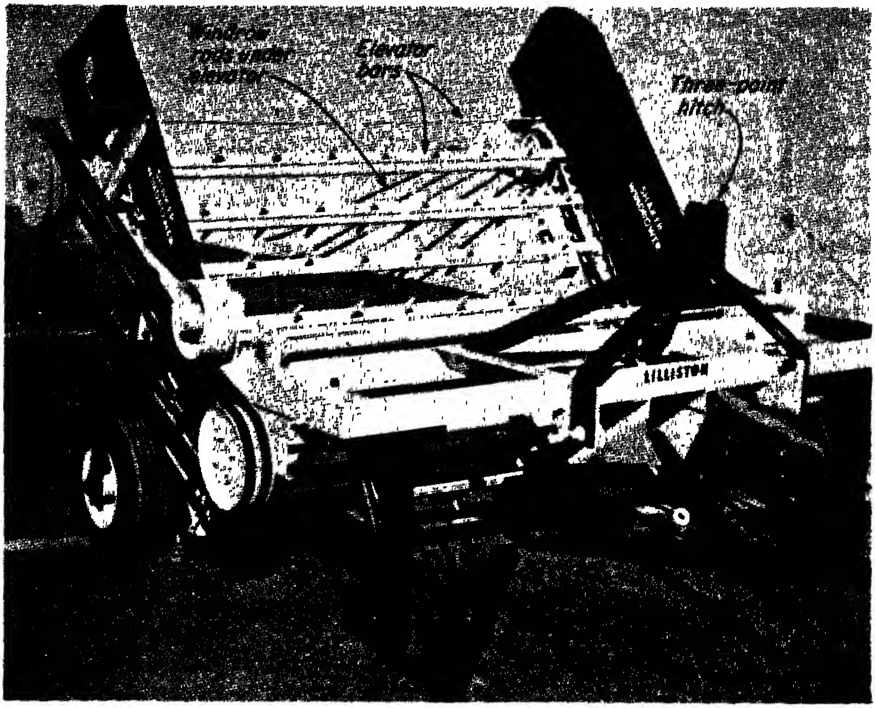

Fig. 21-14. Combination peanut digger-shaker and windrower. (*Lilliston Implement Co.*)

and concave bars. The picker has spring teeth on both the cylinder and concave (Fig. 21-15).

Peanut Combines. The commercial peanut combine embodies all the features of a peanut thresher with the addition of a combination pickup-feeder chute (Fig. 21-16). Peanut combines may consist of special types of peanut combines or of converted grain combines. Many farmers make homemade peanut combines by mounting a stationary thresher on a heavy trailer frame. A pickup-feeder chute is attached to the front, while a long bagging elevator and a high bagging platform are attached at the rear. The machine is operated by an auxiliary engine. The elevator and bagging head and bagging platform should be high enough so that men handling the bags will be above the main dust area of the thresher unit.

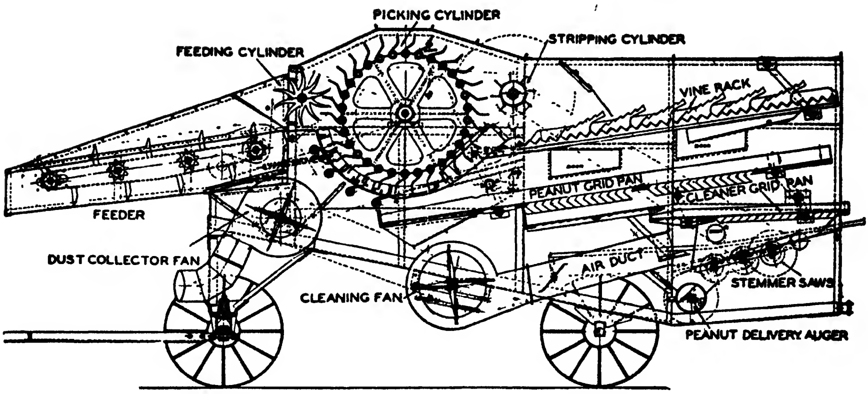

Fig. 21-15. Peanut picker-thresher equipped with spring teeth on cylinder and concaves.

Fig. 21-16. Tractor-drawn peanut combine equipped with auxiliary engine and sacking attachment. (*Texas Agricultural Experiment Station.*)

Peanut combines are usually operated by auxiliary engines that may be mounted either on top of the machine or on a supporting hitch frame. If the engine is not mounted above the machine, a large pipe should extend from the engine radiator to a point above the machine to permit dust and trash-free air to be drawn through the radiator, so that the fins do not become choked. Figure 21-17 shows a tractor-drawn power-take-off-

Fig. 21-17. Tractor-drawn power-take-off-driven peanut combine equipped with tank for the bulk handling of peanuts. (*Lilliston Implement Co.*)

driven peanut combine equipped with a tank for bulk handling of peanuts.

Stokes and Reed[1] state that

> The two most critical phases of combining peanuts are lifting the peanuts off the ground and into the picking unit, and getting the nuts out of the hay. The speed of the pickup unit was found to have a decided effect

[1] C. M. Stokes and I. F. Reed, Mechanization of Peanut Harvesting in Alabama, *Agr. Engin.*, 31(4):175, 1950.

> on the peanuts lost from cured windrows. When the peripheral speed of the ends of the teeth on the pickup was greater than the forward speed of the combine, there was a tendency to either pull the windrows apart and cause loose nuts to drop off or for the teeth to tear through the windrow knocking off peanuts. Reducing the speed of the pickup unit on one machine from 87 to 40 r.p.m. reduced the loss of peanuts by approximately 10 per cent. This made the peripheral speed of the pickup cylinder approximately equal to the forward travel of the combine. Separating the peanuts from the hay was not a particular problem in the regular picker units used as combines, if they were equipped with a hood over the hay discharge to keep tail winds from affecting their operation. It was found, however, that the hay tended to bunch on the racks of some of the converted grain combines. Peanuts were carried over the racks in bunches. The amount of foreign matter left in the peanuts varied with adjustments and could be kept within desirable limits on all three types of machines.

A self-propelled peanut combine is available for picking up windrows of peanuts. It is equipped with bagging attachments and has an industrial gasoline engine for power.

Combined peanuts have a high moisture content and must be dried before storage.

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QUESTIONS AND PROBLEMS

1. Make a list of the root crops.
2. Explain the operation of a potato digger.
3. Explain the differences between harvesting Irish and sweet potatoes.
4. Trace the flow of beets through a beet-digging machine, explaining the action of the different sections of the machine. What is a beet combine?
5. Explain the action of (*a*) a peanut shaker, (*b*) a peanut thresher-picker, (*c*) a peanut combine.

SPECIAL CROP HARVESTING EQUIPMENT

22

Machines are being developed to harvest mechanically almost every kind of farm product grown for market. Sugar cane and castor beans can now be harvested with special self-propelled machines. As new crops gain in importance, special machines are designed, developed, and adapted to their harvest.

SUGAR-CANE HARVESTERS

The mechanical harvesting of sugar cane requires a machine that must perform several operations simultaneously. (1) The green watery tops must be severed and discarded. (2) The tremendous amount of leaf and trash must be removed from the stalks. (3) The stalks must be cut as close to the ground as possible. (4) The stalks must be either placed in piles for loading or put directly into wagons.

Sugar cane is grown in bedded rows spaced about 6 feet apart. The plants grow to a height of 12 to 15 feet, with a diameter of about 1 inch. The plants may be so thick as to average about 1 inch apart in the row. In Louisiana and Florida, the harvesting period ranges from early October to late December. Sugar cane is grown in most tropical countries. The world production of sugar from sugar cane averages approximately 24 million tons annually. It may require 10 tons of sugar cane to produce 1 ton of sugar.

A self-propelled sugar-cane harvester is shown in Fig. 22-1. The leaves are stripped from the standing plants by a series of inclined chains with flexible fingers, traveling in a slanting direction rearwardly as the machine moves forward. The stalks are cut at the top and at the ground with adjustable power-operated knives or disc blades. The severed stalks are conveyed through the machine in a vertical position. It is claimed

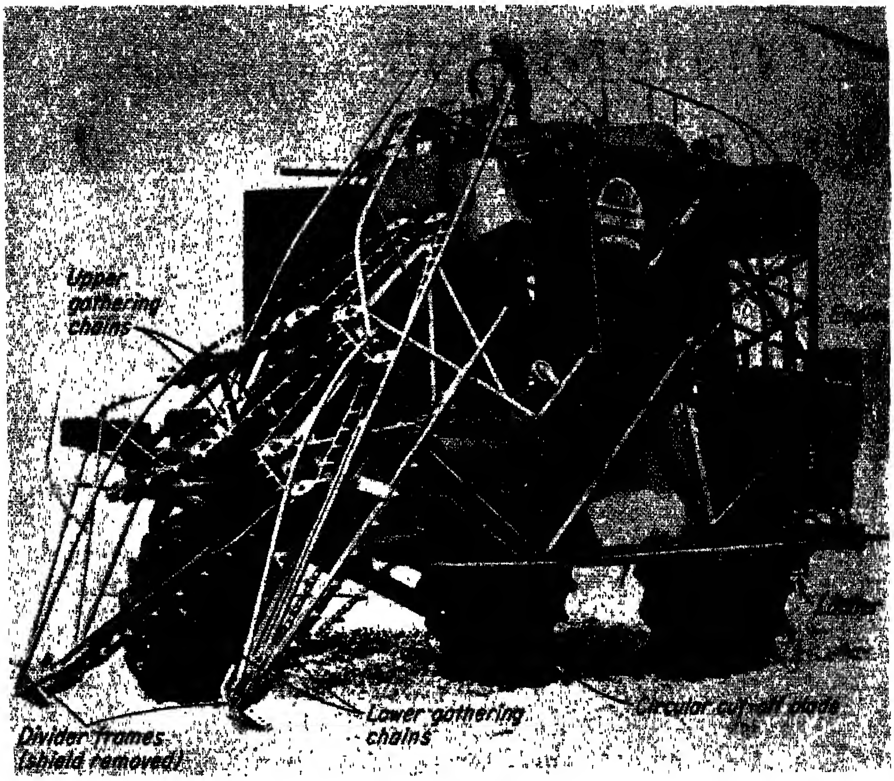

Fig. 22-1. Front view of self-propelled sugar-cane harvester. Note the gathering chains at front and the circular cutoff blade under center of the machine. (*Thomson Machinery Co., Inc.*)

that under Louisiana conditions a sugar-cane harvester can harvest about 180 tons per day. The savings by mechanical harvesting are estimated at $1 to $1.50 per ton.

A self-propelled cane harvester will weigh about 16,000 pounds. It is powered by two 50-horsepower diesel engines. The whole machine is mounted on three rubber-tired wheels. The two rear drive wheels are generally equipped with 13-38 high-lug cane-field tires. The single front steering wheel is equipped with a 11-24 tire.

Fig. 22-2. Sugar-cane harvester in operation. Note how the cane stalks are placed in a windrow by the chain carrier at the rear. (*Thomson Machinery Co., Inc.*)

If the sugar-cane stalks are collected in piles or windrows on the ground, special hydraulic-actuated loaders are available to load the cane onto specially built wagons (Fig. 22-3). The front tongs of the grapple fork are used to drag a bundle of stalks to the open hopper. Then the tongs are closed by hydraulic power and grip the stalks while the boom is lifted and swung over a special cane wagon (Fig. 22-4).

CASTOR-BEAN HARVESTERS

The decline in imports of castor beans with a corresponding increase in production in the Middle Western and Southwestern states of between

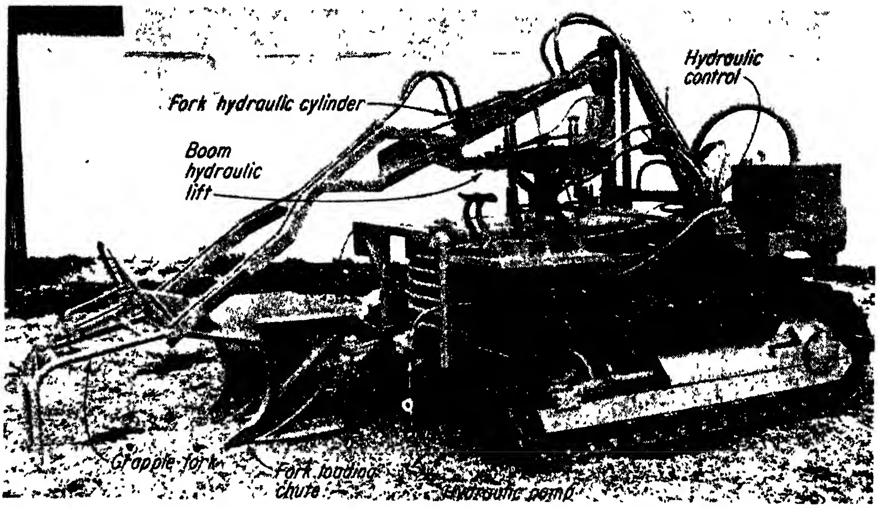

Fig. 22-3. Sugar-cane piler-loader. The boom and the grapple fork are hydraulically controlled. (*Thomson Machinery Co., Inc.*)

100,000 and 200,000 acres has brought about the need for a successful castor-bean harvesting machine. The development of more suitable semi-dwarf shatter-resistant varieties has simplified the machine development.

Cultural equipment for cotton and corn can be used in the production of castor beans.

Plant types can be divided into three groups: (1) dwarf or semi-dwarf (under 4 feet), (2) those of intermediate plant height, and (3) the tall (6-foot) plant group. The plants of group one are the most suitable for mechanical harvesting.

The *racemes*, or clusters of seed, are distributed over the plant somewhat like the bolls on cotton plants. Another similarity to cotton is the characteristic lack of uniform maturity of the seed clusters. At frost, some seed clusters will be mature while others will be in various stages of

development. The well-matured seed clusters have a tendency to shatter easily.

Marketable castor beans are produced in two operations: (1) the removal of the beans from the plants and (2) the hulling of the beans.

Mechanical Harvesters. One machine for harvesting castor beans has some characteristics of a cotton stripper. The beans are stripped from the plants by two long incline-positioned upwardly rotating four-bladed

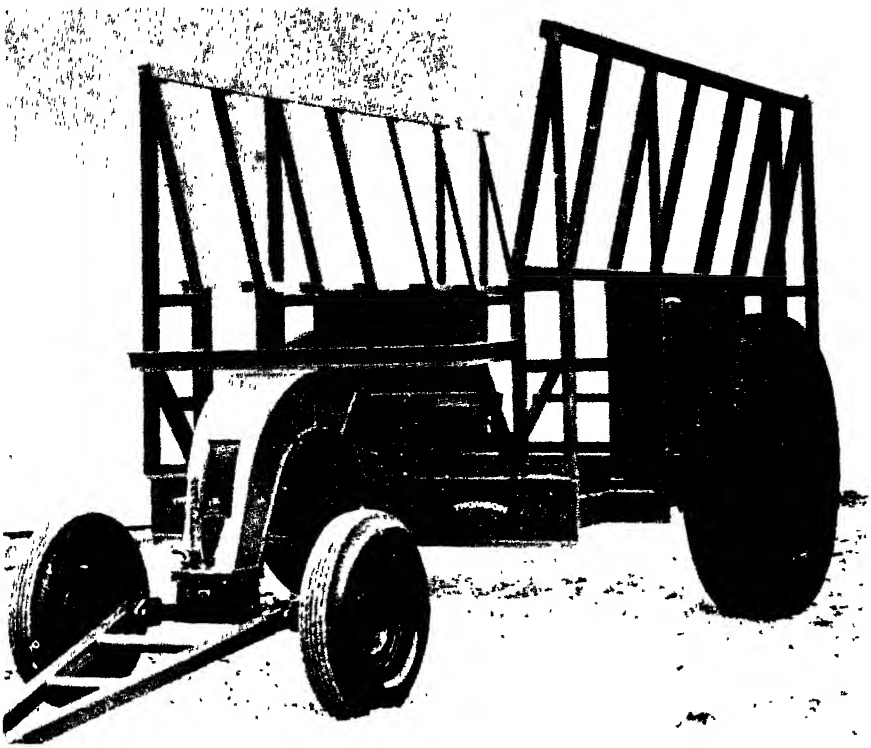

Fig. 22-4. Special sugar-cane wagon. (*Thomson Machinery Co., Inc.*)

paddle beaters. Strips of rubber belting radiating 4 to 5 inches from a central core form the beater roll. The beans fall into a screw conveyor which delivers the beans to a slat-type cleaner. This separates the beans from the trash and stems. The unhulled beans fall on a belt which elevates and delivers them to a trailer wagon.

Tests conducted in Oklahoma with the stripper-type machine showed an average loss of 11 per cent where the machine was operated at 2 to 3 m.p.h. and the beater speeds ranged from 193 to 500 r.p.m.

Figures 22-5 and 22-6 show a castor-bean harvester attachment for a grain combine. The beans are removed from the stalks by a sharp blow

on the base of the plant by hinged arms attached to a rotating disc. The arms are extended by centrifugal force. The harvested beans are pre-cleaned before passing between rubber cylinder and concaves where the hulls or capsules are rubbed from the beans.

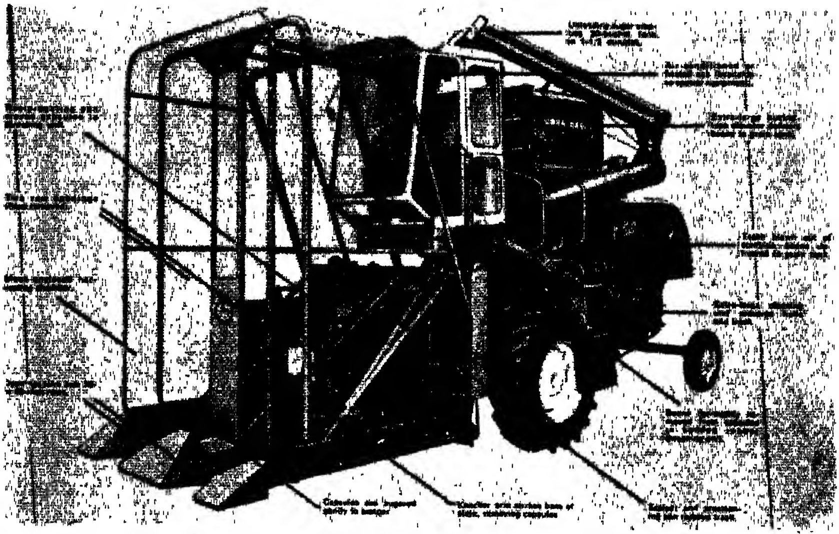

Fig. 22-5. Castor-bean harvesting attachment for a grain combine. The rubber curtains at the front were removed foı this illustration. (*Deere & Co.*)

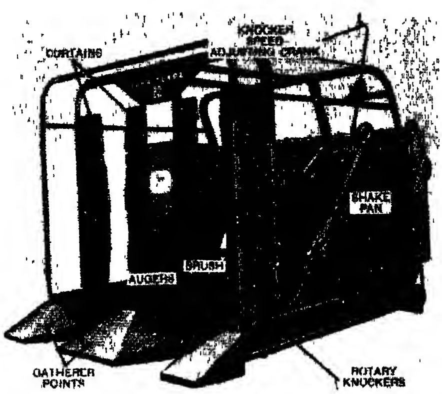

Fig. 22-6. Castor-bean combine attachment showing rubber curtains to prevent the loss of beans. (*Deere & Co.*)

The instruction book lists several changes in the combine, such as the cylinder, concaves, straw walkers, and auxiliary chaffer and shoe.

Castor-bean Hullers. Most of the hand-harvested and mechanically stripped castor beans are hulled in commercial hulling plants. Progress is being made in the development of portable castor-bean hullers. As the

hulled bean is fairly easily cracked, all hulling cylinders and discs are rubber-faced. Some machines have been equipped with cylinders operated vertically and horizontally, and others with inverted cones, but the latest development consists of two horizontal, adjacent, 18-inch rubber-faced discs, one of which is fixed while the other rotates. The hardness of the rubber ranges from 30 to 50 durometer. The variety of the beans, the moisture content, the amount of foreign material, and the type of cleaning equipment are factors that affect the hulling of castor beans.

KENAF FIELD HARVESTER

Kenaf is a soft-bast, long-fiber plant.[1] The seed are planted with a grain drill. The stalks vary in size from ½ to ¾ inch in diameter and grow to a height of 8 to 12 feet. Kenaf has some characteristics of the jute plant grown in India and Pakistan.

The experimental harvesting machine developed by the Florida Field Station of the U.S. Department of Agriculture is a combined harvester and ribboner. A 36-inch swath is cut at the ground, separated from the standing plants, and 12 to 18 inches of the top is cut off. The severed stalks are delivered to a feed table from which they are fed into the crushing unit. Large drums crush and break the stalks and separate the woody core from the fiber. The ribbons of fiber are delivered to the rear of the machine. The fiber is then retted and processed.

SESAME HARVESTING

This is an oilseed crop and is relatively new to farmers of the United States, though it is an old crop in Asia. The first strains introduced and grown in the United States were dehiscent (shattering) types. When the seed pod became mature and dry, it popped open and the seed were lost. Plant researchers have developed indehiscent (nonshattering) varieties. Average yields range from 600 to 1,500 pounds of seed per acre.

The dehiscent types must be harvested with a row binder, and the bundles placed in shocks for a period of 10 to 14 days, after which the bundles are threshed by feeding them into a combine. The combine cylinder speed is reduced, and adjustments of the screens and sieves are necessary. If the seed are cracked, free fatty acids are produced which are unfit for human consumption.

EDIBLE-BEAN HARVESTING

Generally, the beans are cut and windrowed, then threshed with a combine fitted with a pickup attachment. The cylinder speed of the com-

[1] Leonard G. Schoenleber, Machines for New Crops, *U.S. Dept. Agr. Yearbook*, p. 434, 1960.

bine is reduced, and the screens adjusted or changed. Plant scientists are working to develop varieties of beans that grow upright and can be cut and threshed in one operation with the combine.

TREE HARVESTING EQUIPMENT

Mechanical devices are being developed for the harvesting of fruits and nuts. Pickup machines are used to pick up prunes and figs from the ground (Fig. 22-7). Self-propelled catchers and conveyors are used to

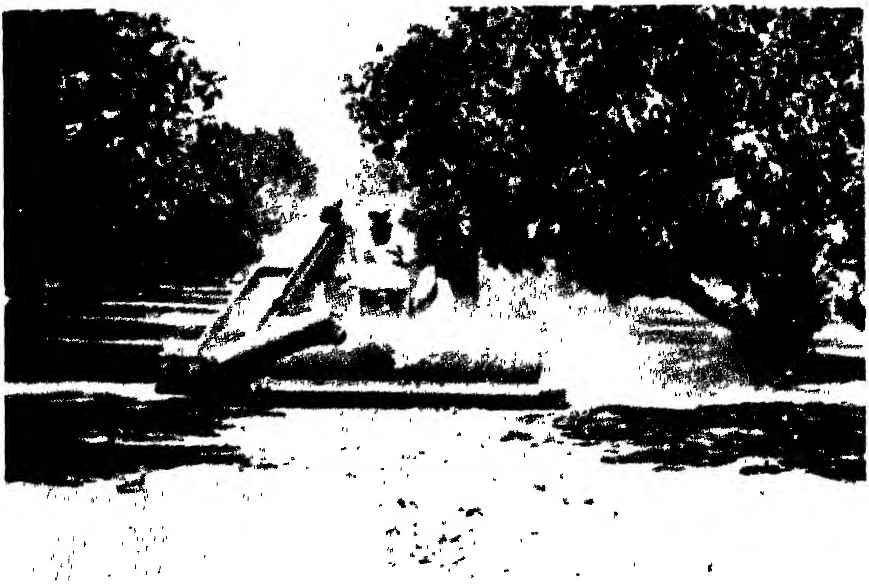

Fig. 22-7. Tree-crop pickup lifting windrowed figs from the ground. (*A. D. Goodwin & Sons, Inc.*)

slip around and under plum and apricot trees so the fruit can be mechanically shaken from the tree onto the catcher-conveyor.

Similar equipment is used to harvest walnuts and pecans.

The catcher consists of a large butterfly-like frame covered with canvas. Long tractor-mounted booms contact the tree limbs. A mechanical or hydraulically actuated knocker agitates and shakes the limbs to loosen the nuts (Fig. 22-8).

Tung nuts are grown along the eastern coastal area of the Gulf of Mexico. The nuts are allowed to mature and fall on the ground to be picked up by hand. Researchers are working to develop a tung-nut rake and pickup machine. A reel of rubber fingers set to operate somewhat like a reel-type side delivery hay rake is being tested to rake the nuts from under the trees and deliver them to an elevator-cleaner.

VEGETABLE OR TRUCK HARVESTERS

A self-propelled conveyor-elevator-loader is used in harvesting lettuce, cabbage, and pineapple. A long conveyor 20 to 30 feet in length extends over the rows so that the hand-harvested heads of lettuce, cabbage, or pineapple can be placed on a belt that conveys them to an elevator that deposits them into a truck.

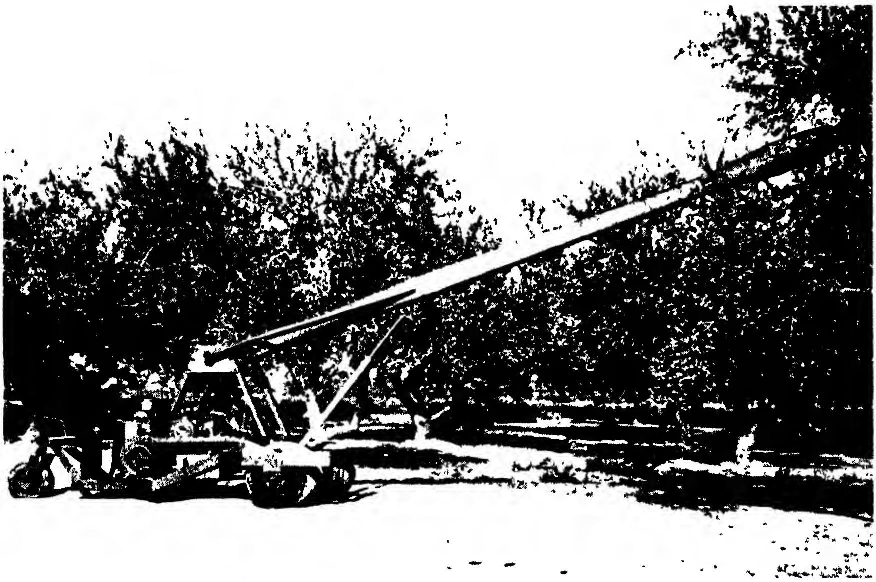

Fig. 22-8. Self-propelled tree knocker equipped with hydraulically operated boom and knocker. (*A. D. Goodwin & Sons, Inc.*)

Machines are being developed to harvest radishes, carrots, cucumbers, tomatoes, grapes, berries, and other vegetable and truck crops.

GRASS–SPRIG HARVESTER

"Grass farmers" of the South have been handicapped in digging sprigs of grasses, such as Coastal Bermuda, to develop better pastures. A sprig digger now available plows up the sod of the well-established grass. The slices of sod are passed under a toothed drum which breaks up dirt and clods, pulls the sod apart, and separates the sprigs into about 6-inch lengths. The drum throws the sprigs onto a separating conveyor which removes excess dirt and discharges the clean sprigs into a trailer. The sprigs are set in the soil by a special sprig planter.

GRASS-SEED HARVESTERS

Machines are available for harvesting grass seed, such as bluestem, side oats grama, and Bermuda. One homemade machine uses long nail-like teeth on a 9-foot drum. The teeth comb off the seed as they come against a steel pan.

Other grass-seed harvesters use large suction fans to pull air through a narrow-slatted hood set close to the ground. Drag fingers ahead of the suction nozzle loosen the seed so they can be drawn into the nozzle. The air discharges the trashy seed into a trailer box.

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QUESTIONS AND PROBLEMS

1. Name several special or minor crops that can be mechanically harvested.
2. Describe the action of a sugar-cane harvester.
3. Describe the action of a sugar-cane loader.
4. Explain how castor beans can be harvested with a combine.
5. What are some of the new crops that are becoming important farm crops?
6. Describe how tree crops can be mechanically harvested.
7. How does a grass-sprig harvester operate?

CROP-PROCESSING EQUIPMENT

23

Crop-processing equipment includes machines that are used to dispose of the crop residue after harvest and machines to process harvested material and put it in a more usable form. Machines that perform such treatments are stalk-cutter-shredders, shellers, feed grinders, and crop dryers.

CROP–RESIDUE DISPOSAL EQUIPMENT

The plants of cotton and corn are left in place in the field after the bolls and ears have been harvested. The stubble and straw of wheat, rice, and sorghum remain in the field. This residue of one crop must be disposed of in some manner before seedbed preparation begins for the next crop. Burning of the residue has long been a thorough way of disposing of crop residue. This method is now in disfavor because soil-improving practices show the need of returning all crop residue to the soil.

Types of Machines for Crop Residue Disposal. Crop-residue disposal machines can be divided into several types: (1) free-rolling trailing cutter, (2) the power-operated flail beater, (3) the power-operated radial-rotating-knife cutter-shredder, and (4) the power-operated horizontal-rotating-knife cutter-shredder.

Free-rolling Trailing Cutters. Where the crop-residue cover is fairly light, the bladed roller shown in Fig. 23-1 will do a satisfactory job of cutting and breaking the stalks into short pieces. Most factory-built rolling stalk cutters have blades long enough to extend across two 40-inch-spaced rows. Farmers in the High Plains area of northwest Texas prefer shop-

built rolling cutters that have a section about 2 feet in length and mount four to five sections in a single hitch-frame. They then can cut four to five rows while traveling at 4 to 5 m.p.h. and can cover 80 to 100 acres per day.

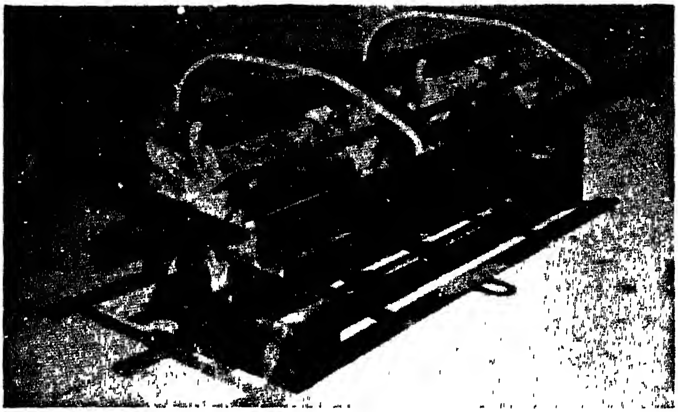

Fig. 23-1. Free-rolling-type stalk cutter. (*E. L. Caldwell & Sons.*)

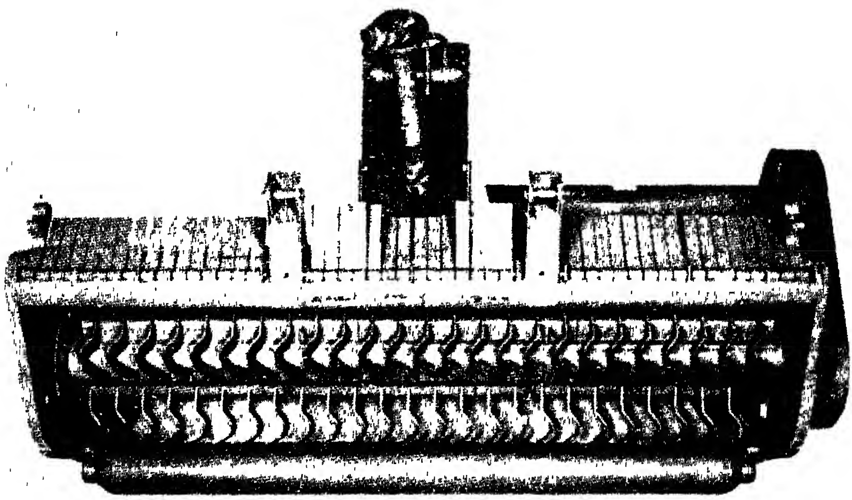

Fig. 23-2. Underside view of flail-type stalk shredder showing cylinder of L-shaped knives. (*Deere & Co.*)

Heavy rolling cutters are used to cut weeds in pastures, and extra-heavy machines are used to cut small brush.

Power-operated Flail Beaters. The beater-type residue-disposal machines generally consist of a horizontal solid or fabricated drum to which are attached rubber flails, steel bars, or steel chains. Hammer heads may be

attached to the end of the bars or chains. The hammer heads or shredding knives may be flat bars, L-, V-, or T-shaped (Fig. 23-3). In some cases the heads are made to be removed. Power is transmitted from the tractor power take-off through a double-universal propeller shaft to a centrally located gearbox. Cross-shafts extend from the gearbox to either one or both ends. The power is transmitted from the cross-shafts to the rotor drum by means of sprocket and roller chain, or V belts. The ratio of the sheave size is arranged to increase the revolutions per minute of the rotor or beater drum to give a peripheral speed to the hammers of about 6,000 feet per minute. Hammer arms of different lengths can be arranged on the rotor to conform to the contour of bedded land.

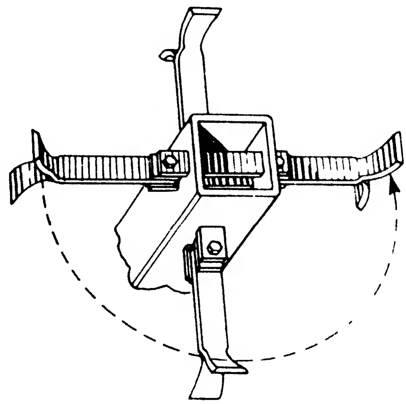

Fig. 23-3. V-shaped flail cutters used on flail-type stalk shredder.

Potato tops can be beaten off on the top and sides of beds, and winter cover crops planted in the furrow can be disposed of with the beater. Rubber flails are used where the vegetation does not contain much fiber. More power is required if the hammers strike the vegetation when they are moving in the direction of travel than if the hammers strike the material rotating opposite to the direction of travel. In the latter case, the material is quickly discharged and the pressure of the hammers

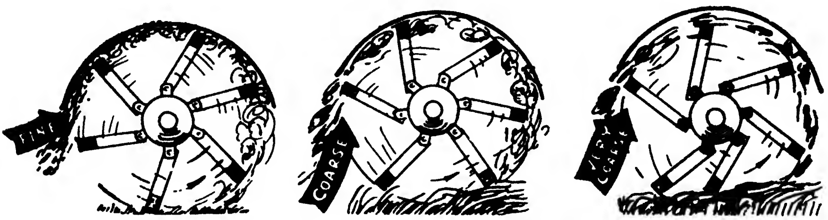

Fig. 23-4. The effects of speed on the performance of beater flails: *left*, high-speed fully extended flails; *center*, dense growth slows flails and requires more power, *right*, flails set low increase power requirements and result in poor cutting.

against the vegetation has a tendency to push the tractor forward. Power requirements will vary with the type and density of the vegetation.

Radial-rotating-knife Cutter-Shredders. The knives of this type of cutter rotate in a vertical plane across the row (Figs. 23-4 and 23-5). The number of knife heads on a machine ranges from two to five. The cutting

knives may be mounted either rigid or hinged. When a machine has only two cutterheads for cutting row-crop residue, the plants are folded into a chute. The knives are positioned at the rear to cut across the end of the chute, using one side of the chute as a shear plate. Machines having three or more knife heads cut across both the row and the middle. Most machines of this type trail behind the tractor, but there are tractor-mounted machines available. All machines are power-take-off-driven.

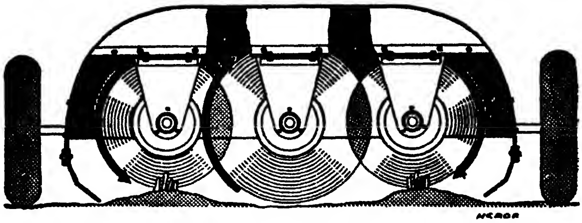

Fig. 23-5. Radial knives cut across the rows; the knives of the cutterheads overlap. The right and center shafts turn clockwise, while the left shaft turns counterclockwise.

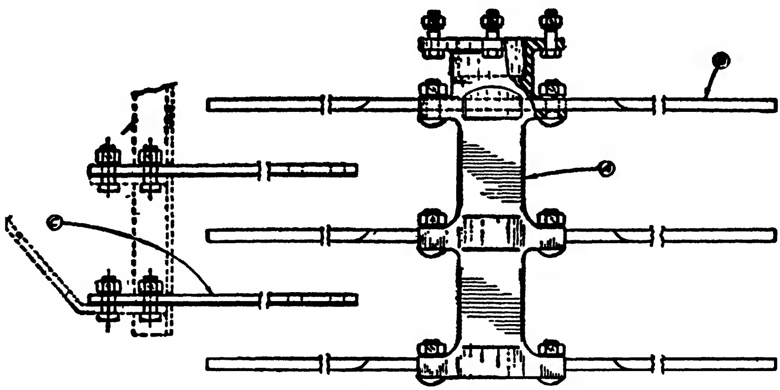

Fig. 23-6. Knife head for three rotating horizontal knives passing between stationary side knives. (*Servis Equipment Co.*)

Horizontal-rotating-knife Cutter Mowers. The knives of this type of cutter rotate in a horizontal plane close to the ground surface (Fig. 23-6). The number of driveheads per machine ranges from one to three. The number of knives per drivehead may range from one to two. Side knives are also used on some machines. The width of swath cut, or the diameter of the cutting circle, on the single-head machines is about 57 inches. The width of swath on the larger machines ranges from 10 to 12 feet.

Power is transmitted from the power take-off to a gearbox on the cutter. When the machine has two or three sets of knives, V belts transmit the power from the gearbox to sheaves for the knife driveheads. Free-swing-

ing hammerlike knives can be used on the ends of the knife bars, which may be either straight or offset as shown in Figs. 23-7 and 23-8.

Rotary cutter-shredder-mowers may be trailed behind (Fig. 23-9), rear mounted, or suspended under the center of the tractor (Fig. 23-10). The trailing types are supported by wheels on each side of the machine. The mounted types can be held at adjustable heights by skids, side, or rear attached wheels.

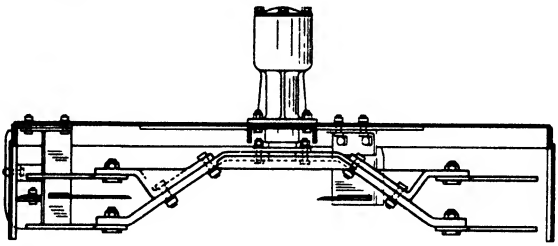

Fig. 23-7. Showing a rotary cutterhead with offset bars to which are attached free-swinging cutting blades. (*Servis Equipment Co.*)

Fig. 23-8. Rotary cutter bars fitted with straight and twisted cutter blades. The sloping part of the twisted blade throws the crop residue upward for finer cutting.

In addition to the disposal of crop residues this type machine can be used to mow weeds in pastures, mow highway shoulders, and the heavy-duty types can be used to cut and shred brush.

Performances of Rotary Cutter-Shredders. Table 23-1 gives the specifica-

TABLE 23-1. SPECIFICATIONS OF STALK CUTTER-SHREDDERS

Machine	Knives					No. of drive-heads	Power require-ments
	Number rotating	Length, in.*	R.p.m.†	Speed of ends, ft. per min.	Direction of rotation		
A	6	27.0	550	8,195	Horizontal	1	Low
B	2	26.5	660	9,124	Horizontal	1	Med.
C	8	13.0	1,070	7,276	Vertical	2	Med. high
D	16	13.0	1,298	8,826	Vertical	3	Med. high

* Length from center of shaft.

† R.p.m. based on power-take-off speed of 550 r.p.m. at full throttle.

SOURCE: H. P. Smith and H. F. Miller, Performance of Stalk Cutter-Shredders,

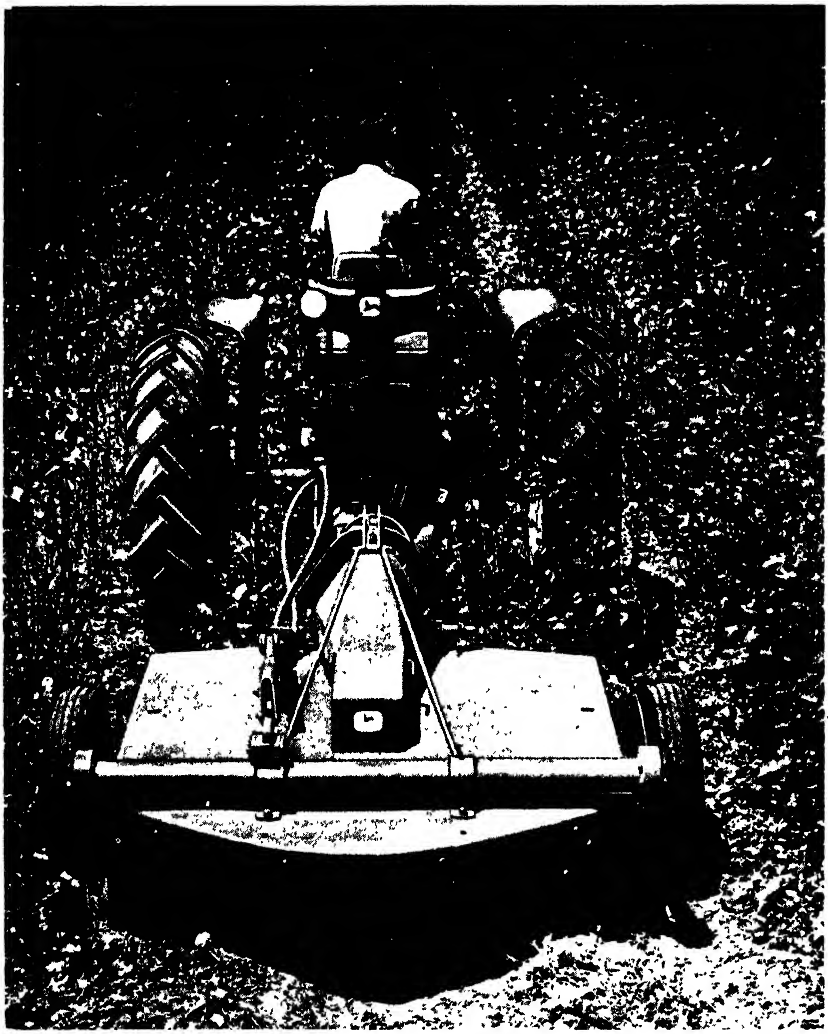

Fig. 23-9. Rotary cutter-mower chopping cotton stalks. (*Deere & Co.*)

tions for four makes of power-operated knife-type cutter-shredders in cutting cotton stalks. From a cultural standpoint, it is desirable to have 90 to 95 per cent of the cut pieces under 6 inches in length.

Effect of Stalk Cutter-Shredders on Insect Control. The graph in Figure 23-11 shows the percentage of pink boll worm larvae killed by two types of crop-residue disposal machines.[1] The conventional machine was

[1] L. H. Wilkes et al.: Stalk Shredder Tests for Pink Bollworm Control, *Tex. Agr. Expt. Sta. Rpt.* 2095, 1959.

equipped with straight horizontal rotating blades (Fig. 23-7), while the modified conventional machine had a blade with a twisted end (Fig. 23-8). The flail-type machine was equipped with forty free swinging chopper knives mounted on a horizontal shaft. The modified rotary blade

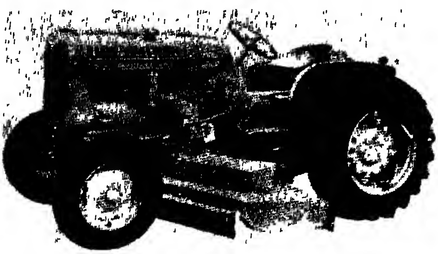

Fig. 23-10. Centrally mounted rotary cutter-shredder. (*Allis-Chalmers Mfg. Co.*)

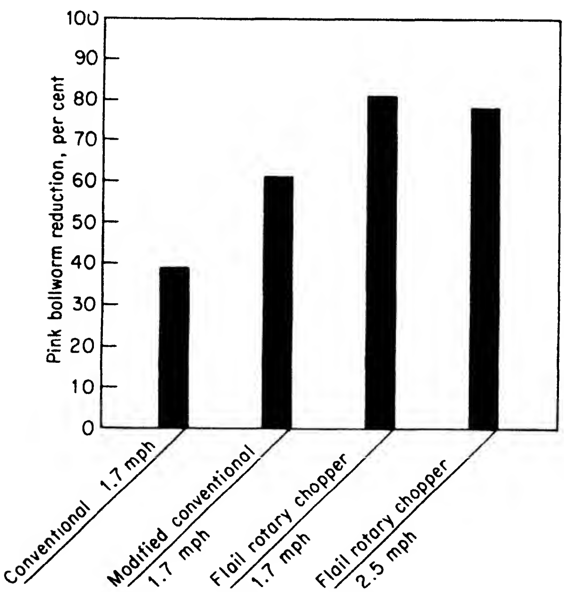

Fig. 23-11. Percentage of pink bollworms destroyed by different types of stalk shredders. The infestation before using the shredders averaged more than 16,000 moths per acre.

gave better results than the straight blade. The highest percentage of larvae killed was with the flail chopper operated at 1.7 m.p.h. with a knife-tip speed of 11,000 feet per minute.

Good results have been obtained in destroying corn borer larvae and other insects present in crop residues.

Flail choppers are discussed as forage harvesters in Chap. 16.

CORN SHELLERS

It seems that the trend in harvesting corn is to shell the corn as part of the harvesting operation. Farmers who grow both small grain and corn use a corn harvesting attachment on the combine and let the threshing unit shell the corn (Chap. 18). Corn farmers are using a shelling attachment in combination with the corn picker (Chap. 19). Where corn is harvested with the husk left on the ear or the husk removed, corn shellers are required to prepare the corn for the shelled-corn market.

Types of Corn Shellers. There are two types of corn shellers: the *spring* and the *cylinder*.

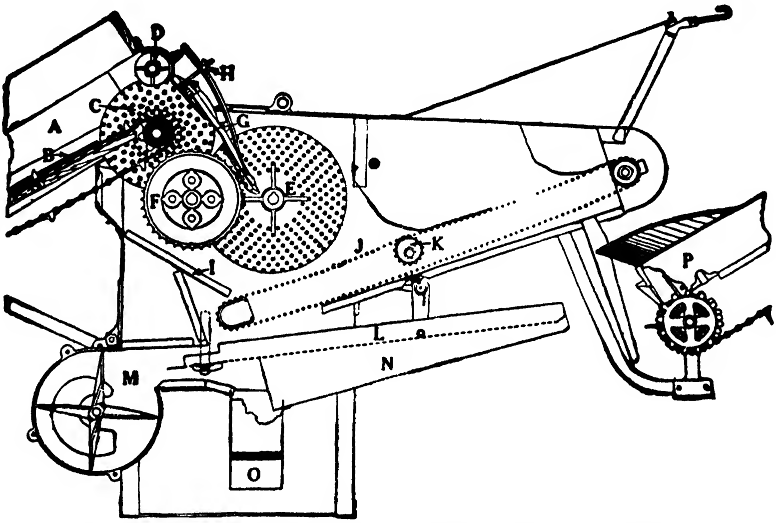

Fig. 23-12 Sectional view of two-hole spring corn sheller

The spring sheller has a plate under spring pressure to hold the ears against a rotating disc which loosens and separates the kernels from the cobs (Fig. 23-12). The kernels pass downward through the cleaning unit, while the cobs are ejected by conveyors.

There are several types of cylinder corn shellers listed as follows:

1. The stationary large industrial and the small farm units. The industrial sizes are used by corn buyers, while the smaller are used on the farm where a large quantity of corn is shelled (Fig. 23-13).
2. Truck-mounted portable auxiliary engine-driven types can be used for custom shelling from farm to farm.
3. Two-wheel trailing portable power-take-off-driven types can be moved to different locations and for custom work.

4. The tractor-mounted power-take-off-driven type has the same general uses as the two-wheel trailing type.
5. The two-wheel trailing auxiliary engine-driven type is used as a husker-sheller unit behind a corn picker (Fig. 23-14).

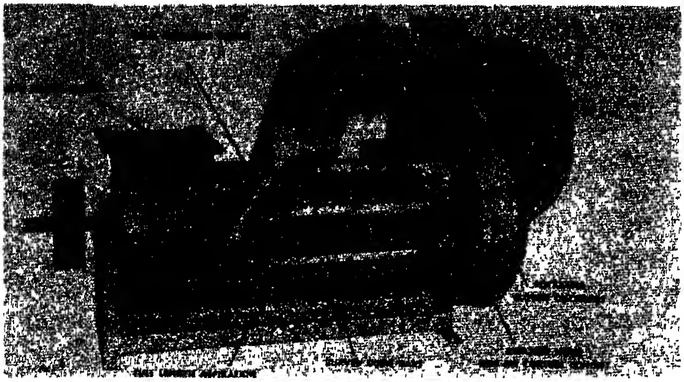

Fig. 23-13. Cutaway view of a stationary corn sheller showing shelling cylinder and screen. (*C. O. Bartlett & Snow Co.*)

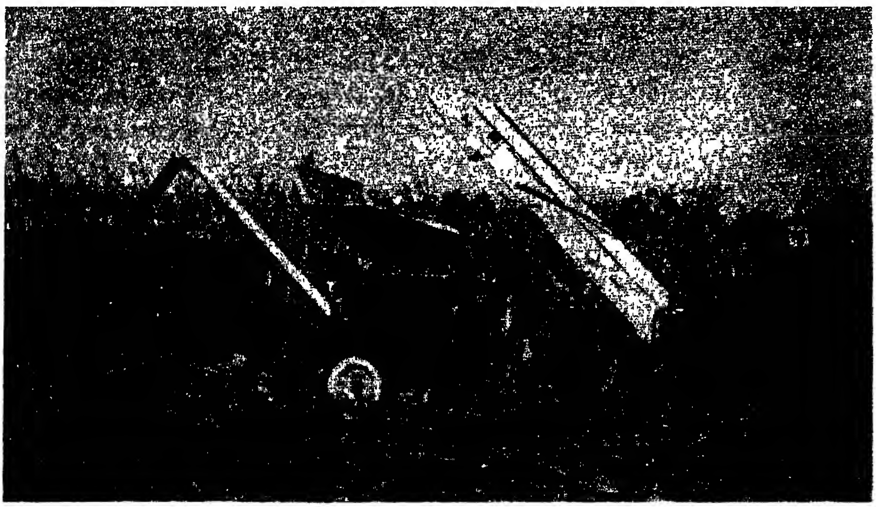

Fig. 23-14. Two-wheel trailing auxiliary engine-driven corn sheller being used behind corn picker. (*Fleischer Mfg., Inc.*)

The power requirements of a corn sheller will vary from 10 to 35 horsepower, the cylinder speed ranges from 600 to 1,000 r.p.m., and the capacity is influenced by the percentage of husk on the ears, the moisture content of the kernels, the rate of feeding, and the size of the cylinder.

The large stationary units will shell 40 to 50 tons per hour, while the smaller portable units will shell from 100 to 250 bushels per hour.

Some corn shellers are equipped with blowers to handle both the shelled corn and the cobs separately. Sacking attachments are available for some of the portable units.

FEED GRINDERS AND MILLS

In the feeding of livestock, it has been found that more animal nutrition and food constituents can be assimilated and put into flesh on an animal if the feed is ground rather than left whole. Every farmer who has any livestock to feed, therefore, would find it advantageous to secure a small feed grinder to grind the feed before it is fed to the stock. Small feed grinders can be operated by gasoline engines or small electric motors. These grinders can be divided into three types, depending upon the method of grinding, namely, the *burr*, *hammer*, and combination *grain-roughage*.

Burr Grinders. Most of the burr feed grinders are equipped with flat, roughened, chilled-iron plates which are often called *burrs;* hence the name *burr grinders*. Burr feed-grinder mills are generally adaptable to grinding husked corn, the small grains, and material of low fiber content.

Hammer Mills. The hammer mill differs from the burr mill in that, instead of flat disc plates for grinding, there are hammerlike projections mounted on a cylinder. This cylinder of hammers revolves at a high rate of speed and grinds the material by beating it to pieces. It is claimed that this type of mill will grind almost any material that is used for feed.

Krueger gives the following advantages of a hammer mill:

1. It is not dulled by running empty.
2. Foreign material in the feed will not ordinarily injure it.
3. There is greater range in fineness.
4. Replacements are fewer.
5. Wear does not impair its efficiency.

Sizes. Hammer-mill feed grinders vary in size from the small compact mill with a direct-connected 1-horsepower electric motor (Fig. 23-15) to the large mill requiring 75 to 100 horsepower to operate it. When a feed hopper is attached to the mill, it will automatically feed itself and requires no attention. Automatic grinding out of a grain bin is practical for farm installations, as shown for roller mills in Fig. 23-17.

Hammers. The hammers are fastened on a cylinder and may be rigid or swinging. The free-swinging hammer is hinged (Figs. 23-15 and 23-16), but the rigid is fastened to a rotor shaft or cylinder by jam nuts.

The shape of the hammer cutting edge varies according to the ideas of the designers. The hammer should, however, be made of high-grade hardened steel to prevent excessive wear.

Screens. In most machines, the lower half of the cylinder is enclosed by a screen, usually of one piece. It consists of holes punched through sheet steel. Various-sized holes are used, depending upon the fineness of grinding desired. The size of the holes ranges from $\frac{5}{64}$ inch to 2 inches.

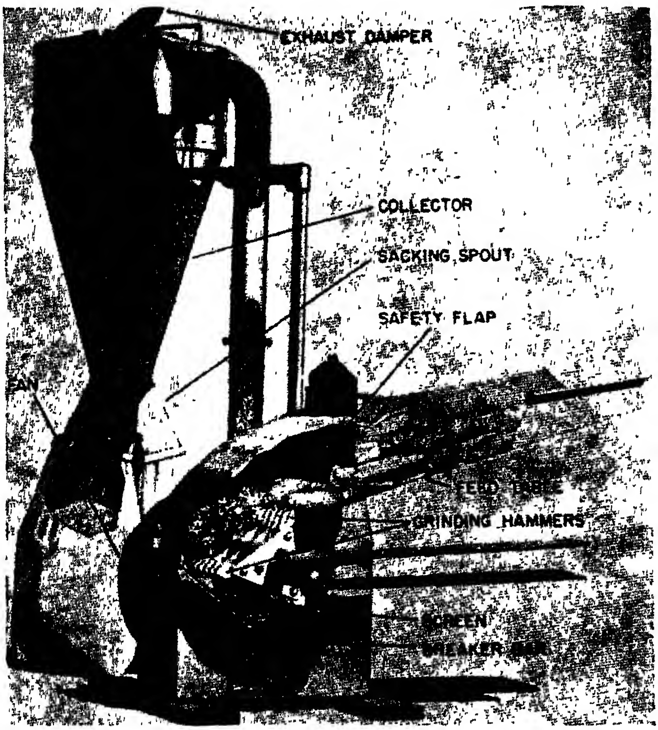

Fig. 23-15. Cross section of hammer mill showing the grinding action and collecting and bagging attachment. (*Deere & Co.*)

The smaller holes are used when grinding grains, while the larger sizes are used when grinding roughage, such as sorghum stalks, cornstalks, or hay.

Grinding Process. The material to be ground is fed directly into the compartment where the hammers are revolving. The hammers strike the material with such violent force that it is practically exploded. The material is retained on the screen until it is beaten fine enough to pass through the perforations.

Capacity and Power. The capacity of a hammer mill depends on many factors, such as the rate of feeding, speed of hammers, power available, kind of material being used, fineness of grinding as determined by size of opening in screen, and size of mill.

Elevating Attachments. The ground feed is removed from under the mill by suction and blown into the large collector hopper, equipped with either a bagging attachment or a swivel spout for delivery into a truck

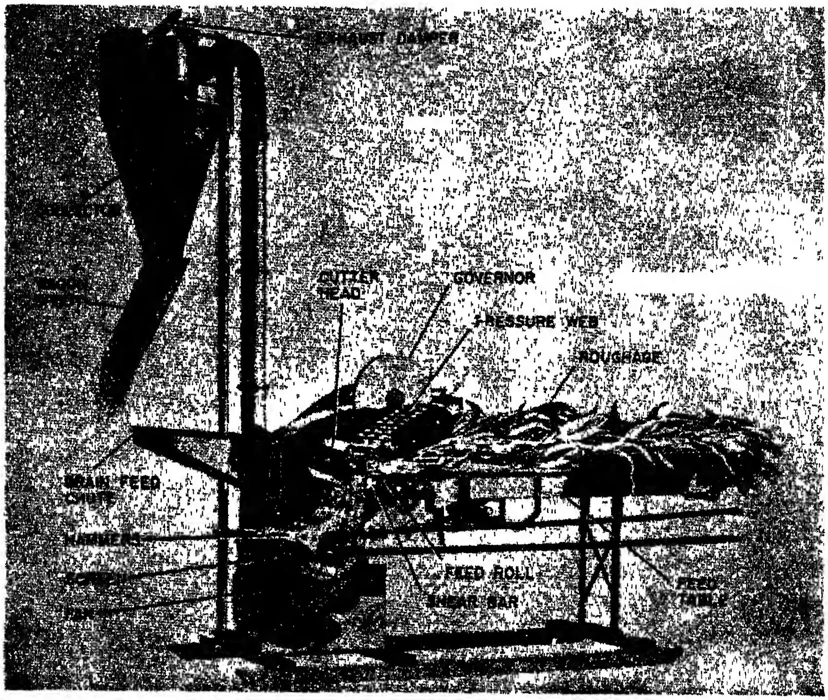

Fig. 23-16. Cross section of combination roughage mill equipped with cutterhead to cut the roughage and hammers to grind the cut roughage and grain. (*Deere & Co.*)

or trailer. The ground material can also be blown directly into the bin. This eliminates most of the dust resulting from the grinding of the feed.

Portable Hammer Mills. When a farmer wishes to do custom grinding, he can mount a hammer feed grinder on a truck so that it can be easily transported from farm to farm with little lost time. Portable mills can be mounted on a trailer cart and operated by the power take-off of the tractor.

Combination Grain-roughage Feed Mills. Figure 23-16 shows a feed mill that chops and grinds both the ears of corn and the stalks, producing a

grain and forage feed. Some machines are equipped with extra hoppers and metering feeds so that small grains and roughage can be ground and mixed as a ration feed. The machine shown in Figure 23-17 grinds and mixes small grains, hay, and shelled or ear corn with concentrates.

Roller Feed Mills. Roller feed mills are equipped with two grooved rollers about 10 inches in diameter. One roller is under spring pressure which

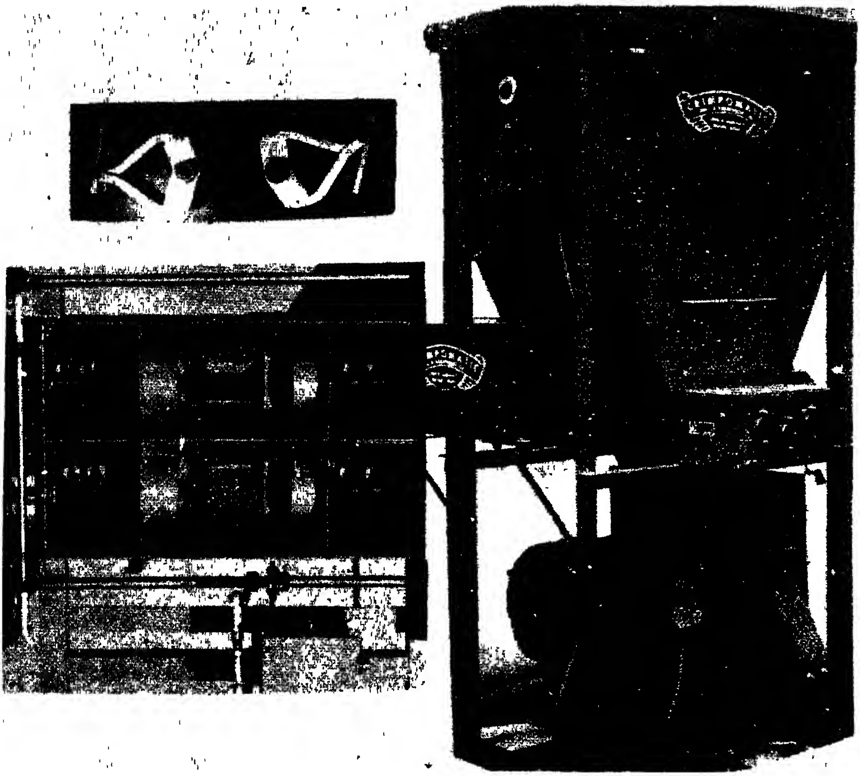

Fig. 23-17. Automatic roller feed mill equipped with electronic controls: *left bottom,* overhead view of four augers feeds; *left top,* the rate of feed can be set on the scale. (*Crimpomatic Mill & Equipment Co.*)

can be adjusted to the desired degree of crushing. The grain passes between the rollers, which crush and crimp the grain. Figure 23-17 shows an automatic roller mill which is electronically controlled. It has four feed augers, so that a complete ration of two to four ingredients can be crushed and crimped simultaneously. Figure 23-18 shows how different kinds of feed are conveyed from storage bins to the mill and a conveyor from the mill to the finished feed bin. The operation is completely auto-

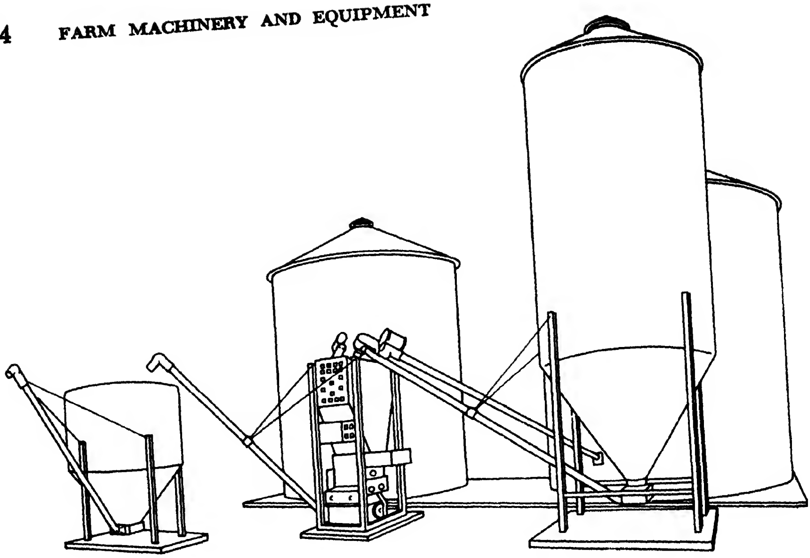

Fig. 23-18. Diagram showing how the automatic feed mill conveying system is arranged. (*Crimpomatic Mill & Equipment Co.*)

Fig. 23-19. Portable power-take-off-driven feed mill that grinds and mixes small grain, hay, shelled or ear corn with concentrates. (*Gehl Bros. Mfg. Co.*)

matic. If any one of the ingredients runs out, the mill is automatically stopped.

FEED MIXERS

When farmers wish to mix two or more ground feeds of known feeding value to obtain a balanced-ration feed, a feed-mixing machine is needed (Figs. 23-19 and 23-20).

Adding of Molasses to Feed. If molasses is to be mixed with the feed, a special molasses pump is required to pump the molasses from a barrel and inject it into the conveyor system so that the molasses is automatically mixed with the feed as it is blown from the housing of the mill (Fig. 23-21).

Pellet and Wafer Feeds. Many commercial feed plants have equipment where the feed is ground, steamed, and squeezed through holes in a plate to make pelleted feed. Field wafering machines were discussed in Chap. 17.

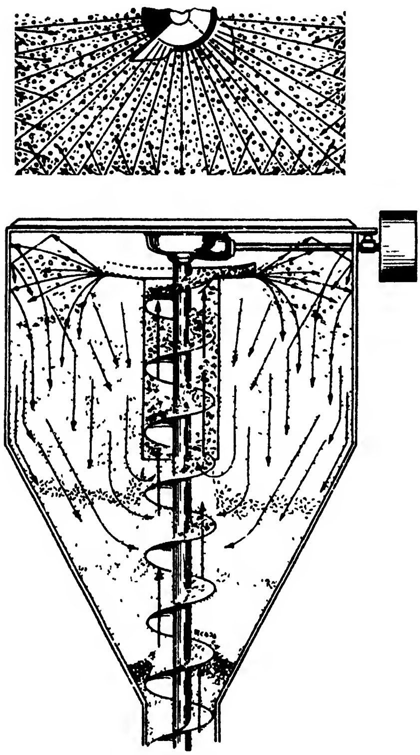

Fig. 23-20. Sectional view of feed mixer: *top*, overhead view, *bottom*, side view.

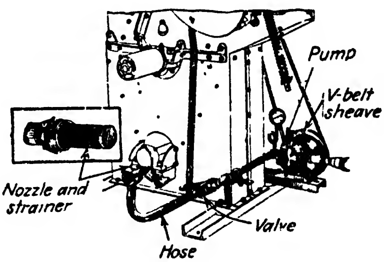

Fig. 23-21. Molasses pump to mix molasses with ground or chopped green feed.

CROP DRYERS

A farm crop dryer may be any structure or contrivance which includes the facilities for the drying or curing of farm crop products with forced, heated or unheated, air.

The drying of fruits by exposure to the sunshine is an ancient practice. The damp climatic condition of England prompted by the people of that

country to investigate artificial drying methods many years ago. Tobacco growers of Virginia and the Carolinas attempted the use of heated air to color tobacco as early as 1830. Heated air for the curing of sweet potatoes was used in the early 1930s. Forced air drying of hay came into use in the late 1930s and early 1940s.

The drying of farm products on the farm and in commercial plants is now an essential phase of agricultural storage and marketing requirements. Many farm products, when harvested, contain too much moisture

TABLE 23-2. MOISTURE CONTENT SAFE FOR STORAGE

Crop	*Moisture, %*
Shelled corn in the bin	13
Ear corn in the crib	16–18
Oats in the bin	13
Wheat in the bin	13
Barley in the bin	13
Sorghum in the bin	12
Rice in the bin	12–13
Soybeans in the bin	11
Peanuts	7–9

for safe storage. Table 23-2 shows the percentage of moisture for safe storage of several crop products.

This discussion embraces only the equipment used on the farm for crop preservation, curing, and drying.

Types of Crop Dryers. There are many types of farm dryers, as shown by the outline below.

- I. Farm-constructed dryers
  - A. Duct-lateral systems
    - 1. Central duct
    - 2. Side duct
  - B. Duct-slatted floor system
  - C. Underfloor plenum-chamber sack
  - D. Trailer-wagon
  - E. Crib and bin dryer and ventilation
- II. Manufactured crop dryers
  - A. Continuous flow
    - 1. Column
    - 2. Horizontal
  - B. Batch
    - 1. Column
    - 2. Crib and bin
    - 3. Piled on wire ducts on floor or ground

Farm-constructed Dryers. The dryers for both hay and grain can be constructed on the farm. The duct-lateral and slatted systems (Fig. 23-22)

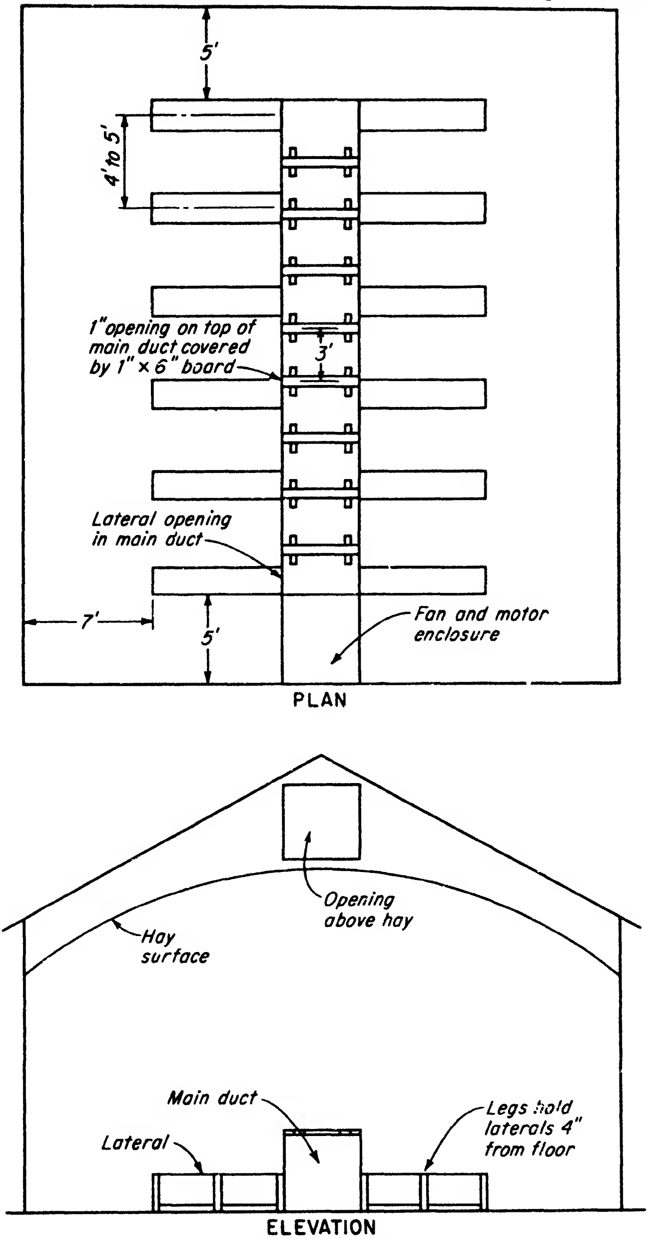

Fig. 23-22. Arrangement of a central duct with laterals for drying long loose hay. (*Illinois Agr. Ext. Ser. Cir.* 757.)

are used primarily for the drying and finishing of hay. The hay dryer or finisher consists of a system of air ducts on the floor of the hay mow or barn on which the hay is placed to a depth of 6 to 10 feet, depending upon the moisture content of the hay. Air is forced through the air ducts and up through the hay by a centrifugal or propeller-type fan driven by an electric motor. With this system, the hay is allowed to cure partially in the field to a moisture content of 45 to 50 per cent before it is placed on the dryer. Unheated air forced through the system will ordinarily dry the hay to 20 per cent in 7 to 14 days, depending upon the outside atmospheric conditions. Alfalfa hay will usually dry in the swath

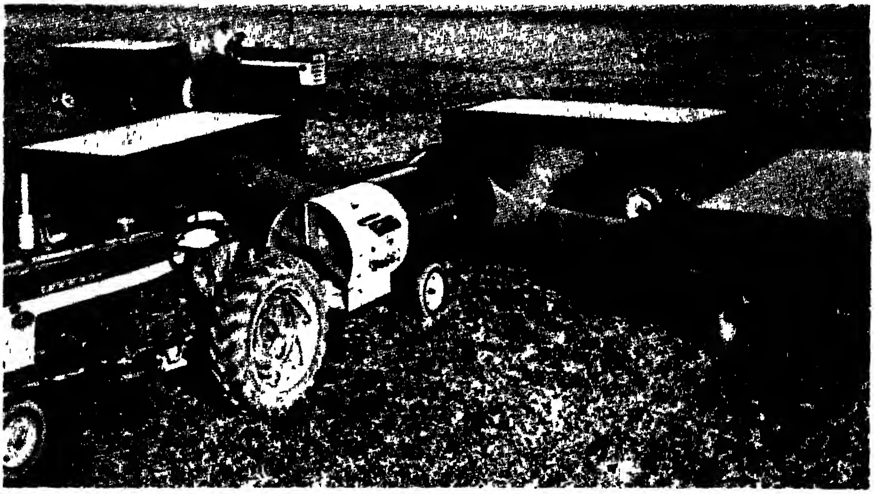

Fig. 23-23. A single heat exchanger can be used to force air through as many as three trailer boxes of grain at the same time. (*International Harvester Company.*)

in midsummer to 50 per cent within 3 to 4 hours after it is cut; therefore, it is possible to get the hay into the barn on the same day that it is cut.

Other types of dryers constructed on the farm are the duct in a trailer or wagon box, crib and bin drying, and specially constructed column batch dryers (Figs. 23-23 and 23-24).

Manufactured Crop Dryers. The manufactured crop dryers can be divided into two classes, namely, the *continuous flow* and the *batch*. The continuous-flow types are available as tower dryers (Fig. 23-25) and as horizontal dryers. A portable batch dryer is shown in Fig. 23-26.

Heat Exchangers or Furnaces. A heat exchanger is a unit which draws in cold air and heats it as it passes through the unit into the drying section. In a sense, cold air is exchanged for heated air. The unit has a furnace for heating the air and a fan to move the air. The heat exchangers shown

in Fig. 23-27 are generally termed *crop dryers*, but they really are only a part of the complete dryer. The product to be dried is in a separate unit, having ducts, chambers, or passages to conduct and direct the air through the product.

There are two general types of heat exchangers, the *direct* and *indirect*. The direct type draws the air past the burner and flame and blows heated air and burned gases directly through the product to be dried. In the indirect type, the flame and gases flow around air tubes and pass out a

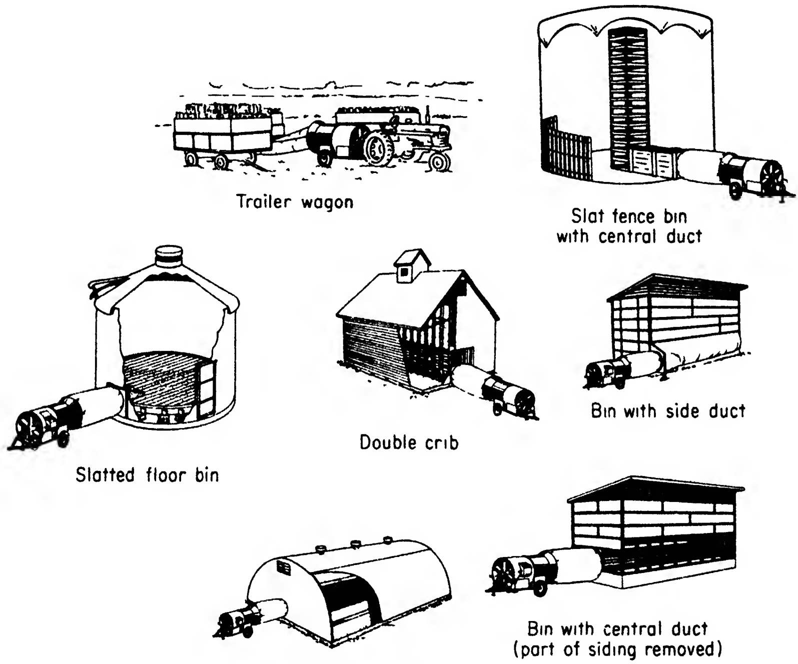

Fig. 23-24. Types of drying bins and systems. (*International Harvester Company.*)

vent. The hot air blown into the hay or grain is drawn through the tubes. Some drying outfits have the flame from the burner directed into the fan intake or into an intake tube extending out at least two diameters of the intake.

Burners. Oil and gas burners are used in heat exchangers. There are two types of oil burners, the *pressure-atomizing* and the *pot*. In the *pressure-atomizing* burner, the oil is pumped under pressure and the rate of burning controlled by a nozzle of the desired size. In the *pot* burner, the oil flows into a round pot. The draft of the regular fan or an auxiliary fan aids in atomizing the fuel.

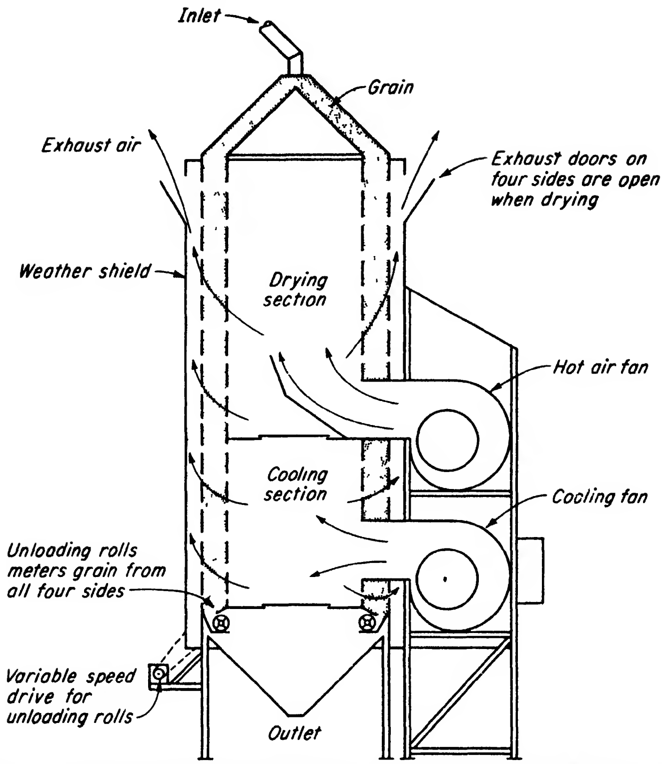

Fig. 23-25. Continuous-flow column dryer. (*Grain Drying Equipment Co., Inc.*)

Natural or LP (liquid petroleum) gas burners are low-pressure burners and operate with 1 to 30 pounds of gas pressure. Some types may operate with pressures as low as 4 ounces.

Fuels. The type of fuel used for a burner or drying system is recommended by the manufacturer. Different types of fuel have different Btu ratings as shown in Table 23-3.

TABLE 23-3. HEAT CONTENT OF VARIOUS FUELS

Fuel	Btu per gal.	Btu per cu. ft.
Natural gas	....	1,000
Butane	104,000	3,400
Propane	92,000*	2,570
Kerosene	144,000	
Gasoline	117,000	
Fuel oil	130,000	
Distillate	135,000	

* Vapor per gallon of liquid at 60°F. and 30 in. mercury = 36.4 cu. ft.

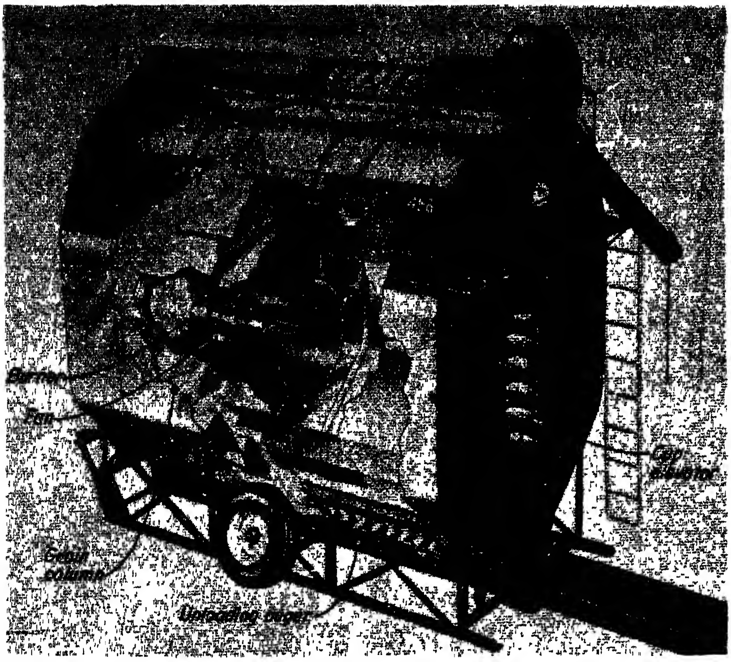

Fig. 23-26. Cutaway view of batch dryer. (*Deere & Co.*)

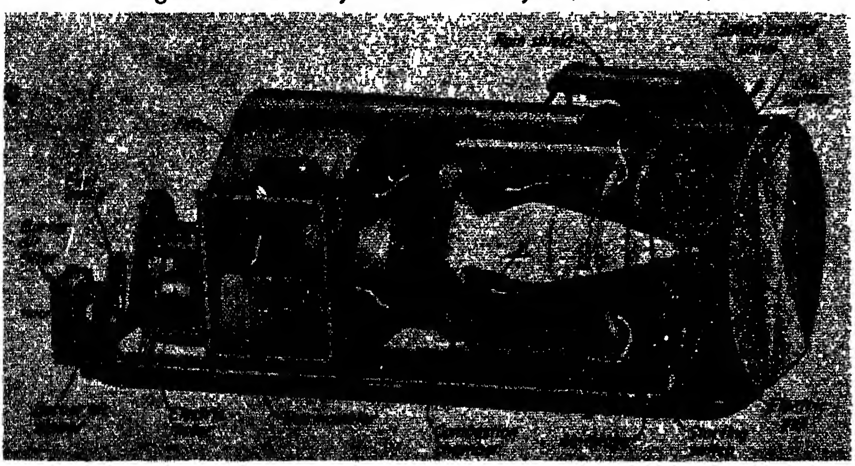

Fig. 23-27. Sectional view of a heat exchanger. (*Campbell Dryer Co.*)

Types of Fans. The *centrifugal*, or *multivane*, type of fan is designed to deliver large volumes of air over a wide range of pressures. It is made in *straight*, *forward-curve*, and *back-curve* types, depending upon the shape of the impellers, or blades (Fig. 23-28). The forward-curve fans operate at relatively low speeds but vary widely in volume of air delivered

and power required against varying static pressures.[2] The back-curve fans operate at approximately twice the speed of the forward-curve but give a more uniform air delivery and power demand against widely varying static pressures. The straight radial-blade fan operates at a speed between the forward- and backward-curve fans. The number of blades in a backward-curve fan may range from fourteen to twenty-four, the number in a forward-curve fan may range from thirty-two to sixty-six, while the straight radial-exhaust fan may have from five to twelve blades. Pressure-blower and supercharger types may have up to twenty-two blades.

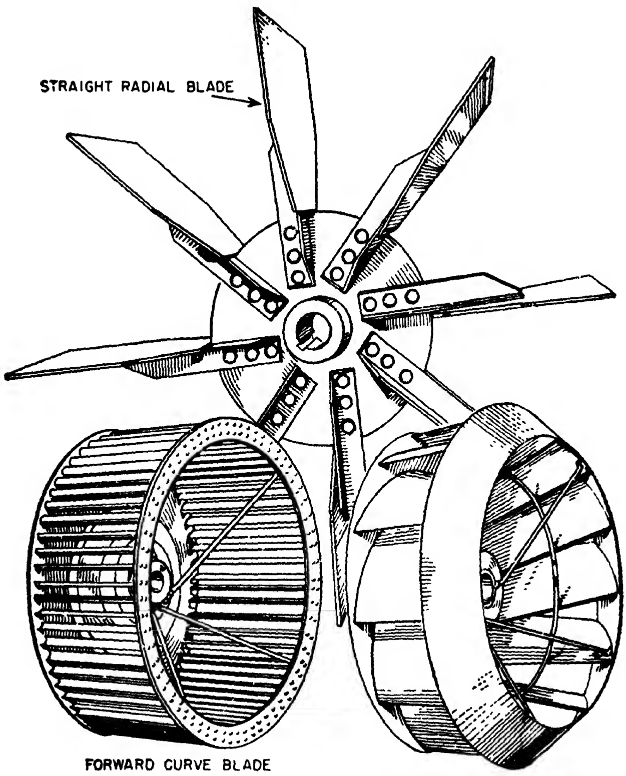

Fig. 23-28. Types of fan blades used with centrifugal fans.

Centrifugal fans are made in both single- and double-inlet types, de-

[2] *Static pressure* is the force exerted by the fan in forcing air through a duct system. It is usually expressed in *inches water column*, or the distance the pressure will depress a free column of water in a U tube.

pending upon whether the air enters one or both sides of the fan housing. Most fan manufacturers have developed lightweight, light-duty centrifugal fans in sizes up to 24 to 30 inches (size refers to diameter of rotor or fan blades), especially designed for use in air-conditioning systems where static pressures rarely exceed $1\frac{1}{2}$ to 2 inches water column. These are available in either single- or double-inlet types. In some cases, two or more fan units are mounted on a single shaft for increased capacity.

The heavy-duty centrifugal fans are made in both forward- and backward-curve types and in a wide range of sizes from about 12 inches up to 180 inches or more. The heavy-duty fans are ordinarily used when the amount of air required exceeds the capacity of the larger sized light-duty fans.

Propeller-type or *axial-flow* fans are designed to deliver large volumes of air against relatively low static pressures (Fig. 23-29). They operate at relatively high speeds and are somewhat noisy. Most propeller fans are designed for operation against static pressures of $\frac{3}{4}$ inch water column or less, although some special types will operate against pressures of 3 inches or more. The ordinary *attic ventilator* type of propeller fan designed to exhaust into open air is not satisfactory for use with hay or grain dryers. The introduction of heat into the air stream of a drying system using a propeller-type fan is somewhat more complicated than with the centrifugal-type fans.

The fan selected should deliver an air flow under the existing static pressure sufficient to carry away the moisture from the product being dried. Different crop products of hay and seeds offer different resistance to air flow as shown in Table 23-4 and Fig. 23-30.

Fan Laws. The following general fan laws apply to all types of fans.

1. The air capacity in cubic feet per minute varies as the fan speed. (Twice the speed results in twice as much air.)
2. The developed pressure varies as the square of the fan speed. (Twice the speed results in four times the pressure.)
3. The required horsepower varies as the cube of the fan speed. (Twice the speed will result in a requirement of eight times as much power.)

Example: A fan running at a speed of 473 r.p.m. delivers 14,850 c.f.m. against a resistance of $\frac{3}{4}$ inch water gage and requires 3.18 horsepower.

If 16,850 c.f.m. were required, what would be the speed, the pressure, and the horsepower?

Use the first law to find the required speed:

$$\text{Speed} = \frac{16{,}850}{14{,}850} \times 473 = 537 \text{ r.p.m.}$$

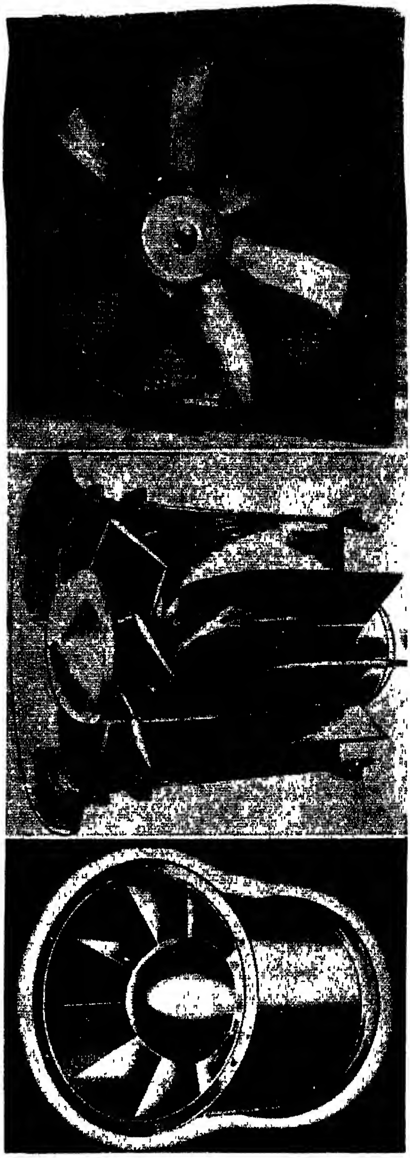

Fig. 23-29. Axial flow fans. (*Aerovent Fan & Equipment, Inc., and Hartzell Propeller Fan Co.*)

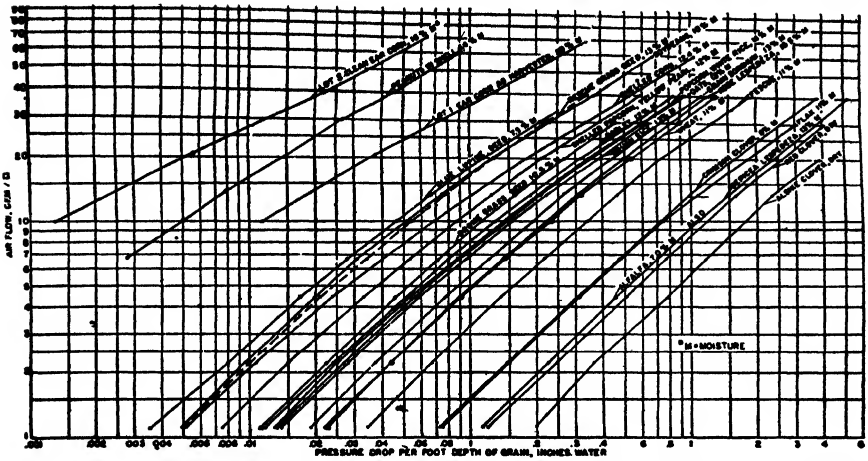

Fig. 23-30. Chart showing resistance to air flow of grain and seeds. [*Agr. Engin.*, 34(9):617, 1953.]

TABLE 23-4. RESISTANCE TO AIR FLOW OF GRAINS AND SEEDS

Kind and condition of grain*	Loose fill		Packed fill	
	Lb. per cu. ft.	Pressure ratio†	Lb. per cu. ft.	Pressure ratio†
Ear corn (clean)		1.00		
Ear corn (94.6 clean)		1.00		
Peanuts in shell (farmer's stock)	14.0	1.00	14.9	1.54
Rescue grass seed (clean)	11.9	1.00	13.7	1.65
Soybeans (clean)	47.4	1.00	49.9	1.41
Shelled corn (Yellow Dent) (clean)	45.6	1.00	47 7	1.34
Barley (clean)	37.3	1.00	39.9	1.46
Oats (clean)	33.0	1.05	36 1	1.73
Rough rice (clean)	38.2	1.00	40.6	1.32
Grain sorghum (clean)	47.4	1.00	50.0	1.41
Wheat (clean)	49.8	1.00	51.8	1.30
Crimson clover seed (clean)	47.4	1.00	51 3	1.44
Crimson clover seed (unclean)	29.5	0.60	32.1	1.01
Flax seed (clean)	42.4	1.00	44.4	1.27
Alfalfa seed (clean)	50.2	1.00	53.6	1.46
Sericea Lespedeza seed (clean)	49.1	1.00	51.8	1.50
Sericea Lespedeza seed (unclean)	44.0	1.03	46.6	1.55
Red clover seed (clean)	50.1	1.00	52.2	1.42
Alsike clover seed (clean)	50.2	1.00	53.4	1.49

* Arranged in order of resistance as in Fig. 23-30.

† To find pressure drop per foot depth of grain, read the pressure from Fig. 23-30 and multiply it by this ratio.

SOURCE: C. K. Shedd, Resistance of Grains and Seeds to Air Flow, *Agr. Engin.*, 34(9):618, 1953.

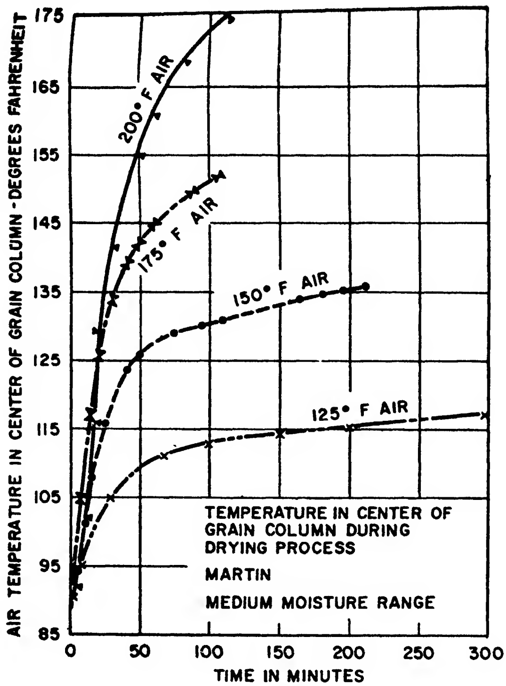

Fig. 23-31. Temperature in sorghum grain and time required for drying at four temperature ranges. (*Texas Agricultural Experiment Station Bul.* 710.)

Use the second law to determine the pressure:

$$\text{Pressure} = \left(\frac{537}{473}\right)^2 \times 0.75 = 0.97 \text{ in. water gage}$$

Use the third law to determine the horsepower:

$$\text{Horsepower} = \left(\frac{537}{473}\right)^3 \times 3.18 = 4.67$$

4. If the air handled by the fan is of a different density from standard air, due to temperature, barometic pressure, or altitude, it becomes necessary to convert the conditions to standard air conditions in order to select the fan from the performance tables.

Effect of Temperature on Rate of Drying Grain Sorghum. Tests conducted in Texas on the drying of grain sorghum indicate that the drying cycle for Early Hegari and Martin consists of at least two stages. The first stage is the evaporation of the surface moisture. The second stage is the diffusion of the moisture from the inside of the kernel to the surface, where it is absorbed by the air moving through the grain column. The

velocity of the air is an important consideration during the first stage, as it governs the rate of drying. The drying rate during the second stage depends on the rate of diffusion. With the higher air temperatures, the rate of diffusion is high at first, but as the drying advances, this process becomes slower, with the drying rate falling off rapidly near the end. The ultimate time of drying is, therefore, governed by the rate of both surface moisture removal and diffusion. The charts in Figs. 23-31 and 23-32 show the effect of four ranges of temperatures on the time required

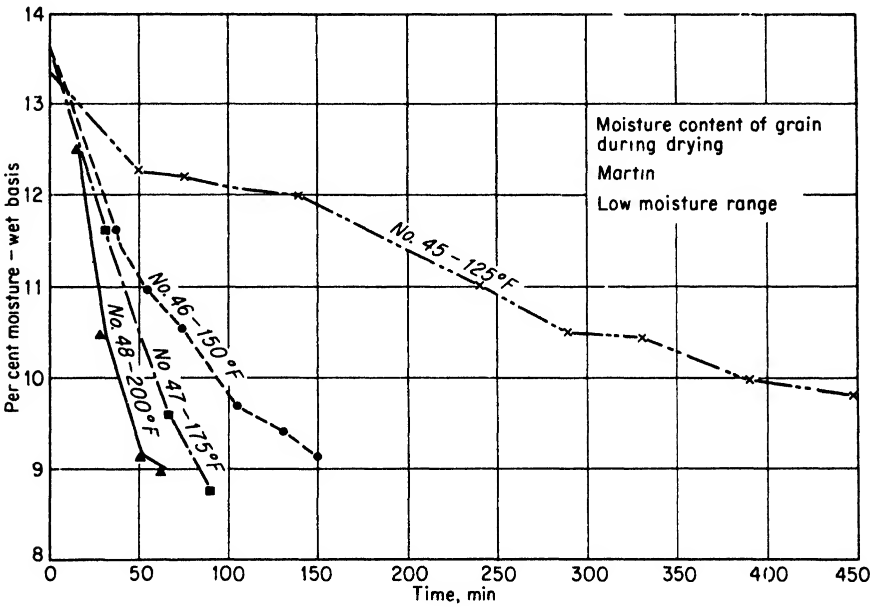

Fig. 23-32. Moisture content of sorghum grain and time for drying at four temperature ranges. (*Texas Agricultural Experiment Station.*)

for drying sorghum grain and the moisture content of the grain during the drying period.

Some crop products are damaged when treated with air of high temperature. Table 23-5 shows that seed corn, grains, and rice have a maximum drying temperature of 110°F., while shelled corn and sorghum grain can be dried at temperatures up to 160°F.

In column-type dryers, the temperature used depends on the type of dryer.

Water Removed in Drying Hay. The number of pounds of water removed per ton in drying hay is shown in Table 23-6.

Distribution of Air Essential for Uniform Drying. Data obtained in tests with many crop materials dried in various types of dryers indicate that the

distribution of the air through the product is an important factor in uniform drying throughout the product. The design of the duct laterals for hay as well as the design of the over-all structure must be considered. Open-mesh prefabricated ducts have given excellent results in drying both hay and grain.

TABLE 23-5. MAXIMUM DRYING TEMPERATURES FOR SOME GRAINS AND SEEDS

Grain	*Max. drying temperature*, °F.
Ear corn	130
Shelled corn	140–160
Hybrid seed corn	110
Wheat	140
Oats	140
Barley	110
Rice	110–120
Grain sorghum	150–200*
Seed grains	110
Soybeans	130

* Depending upon the moisture content.

TABLE 23-6. WATER REMOVED IN DRYING HAY

Moisture content, per cent (wet basis)		Water removed per ton of dry hay, lb.
Beginning	End	
80	20	6,000
65	20	2,570
60	20	2,000
50	20	1,200
45	20	910
80	10	7,000
65	10	3,140
60	10	2,500
50	10	1,600
45	10	1,270

SOURCE: P. T. Montfort, Supplemental Heat in Barn Hay Curing, *Agr. Engin.*, **28**(3):95–97, 1947.

Drying with Heated and Unheated Air. The use of heated air increases the rate of drying, as heated air has a greater moisture-carrying capacity. The heat causes the moisture from inside the hay stem or grain kernel to diffuse to the surface, where it can be absorbed by the heated air flowing through the mass. The use of heated air, however, requires air-heating equipment, fuels, safety controls, and close attention.

The unheated air is used extensively in connection with the barn dry-

ing of hay by means of the duct-lateral and slatted floor systems. Grain, rice, and other crop products have been successfully dried with unheated air. The time required is much longer than that required when heated air is used. The humidity of the natural air must be fairly low to permit drying of the product. An increase in the volume of air will also permit an increase in the depth of the product being dried.

TABLE, 23-7. ECONOMICS OF DRYING

(1) Moisture content, %	(2) Lb. water per bu.*		(3) Equivalent value, \$ per bu.	(4) Discount price, \$ per bu.‡	(5) Gain if dried, \$ per bu.	(6) Bu. required to break even, 2½¢ total per bu.§
	Actual	Excess				
12	6.5			1.000		
13	7.1			1.000		
14	7.7			1.000		
15.5	8.7	Standard	1.000	1.000		
16	9.0	0.3	0.994	0.985	0.009	
17	9.7	1.0	0.982	0.955	0.027	
18	10.4	1.7	0.970	0.925	0.045	33,250
19	11.1	2.4	0.959	0.895	0.064	17,051
20	11.8	3.1	0.947	0.865	0.082	11,667
21	12.5	3.8	0.935	0.825	0.110	7,824
22	13.3	4.6	0.923	0.785	0.138	5,885
23	14.2	5.5	0.911	0.745	0.166	4,716
24	14.9	6.1	0.899	0.695	0.204	3,715
25	15.8	7.1	0.888	0.645	0.243	3,050
26	16.6	7.9	0.876	0.595	0.281	2,598
28	18.4	9.7	0.852	0.495	0.357	2,003
30	20.2	11.5	0.828	0.395	0.433	1,630

* Based on 47.32 pounds dry matter per bushel at 15½ per cent moisture.

† Value of dry matter content = market price × [(100 − initial %)/(100 − final %)].

‡ Typical discounts: No discount for up to 15½ per cent moisture, 1½ cents per bushel for each ½ point up to 20 per cent, 2 cents per bushel for each ½ point between 20 and 23 per cent, 2½ cents per bushel for each ½ point over 23 per cent.

§ Typical annual fixed cost of ownership of \$665 includes amortization over 10 years interest, taxes, insurance. Number of bushels to break even (column 6) = [annual fixed cost (\$665 typical)]/[gain (column 4) minus drying cost per bushel (2½ cents typical)].

Economics of Drying. The data in Table 23-7 show how drying affects the value of farm products.

DEFINITION OF TERMS USED IN DRYING[1]

AMBIENT—Surrounding.

BTU—British Thermal Unit is a common measure of quantity of heat. One BTU will raise the temperature of one pound of water 1°F.

[1] Prepared by the Campbell Dryer Co.

It is approximately the quantity of heat released when a common wood kitchen match is completely burned. If the rate of burning was constant and the match was consumed in one minute's time the rate of heat release would be 60 BTU per hour.

BUSHEL—A bushel is a volume of approximately 1¼ cubic feet. By common use a bushel of ear corn is the volume that will yield a bushel of shelled corn at 15.5% moisture. This will vary between 2½ and 2¾ cubic feet depending upon the original moisture content of the ear corn. . . .

CFM—Cubic Feet per minute is the most common measure of quantity of air flow.

DRYING AIR—The air being passed through the product which is being dried.

DRYING TEMPERATURE—The temperature of the air entering the material being dried. In a conventional batch dryer it is the temperature of the air in the plenum chamber.

EXCESS FLOW VALVE—A check valve which permits flow of gas in either direction but which closes to prevent excessive flow in one direction. If a line is broken down stream of such a valve, the valve automatically shuts off or limits the gas flow.

LP GAS—A mixture of gaseous petroleum products normally stored and transported as a liquid under pressure. Unless otherwise specified the term LP Gas usually refers to commercial propane.

MOISTURE CONTENT—As normally used in connection with grain drying it is the percentage ratio by weight of water in a crop to the weight of water-plus dry material, or wet basis moisture content.

$$Mw\% = \frac{\text{weight of moisture}}{\text{weight of wet material}} \times 100$$

ORIFICE—The opening through which gas is admitted to the burner. For a given gas pressure the rate of flow of gas will depend on the orifice size.

PLENUM—An enclosed volume of gas or air under different pressure than that surrounding the container. In a conventional batch dryer the heated air is forced into a plenum chamber before entering the grain column.

PRESSURE REGULATOR—A mechanical device in a gas line which reduces relatively high and variable inlet pressure to a relatively lower constant outlet pressure. In an LP burner system the regulator delivers gas at a constant pressure to the dryer control system even though the tank pressure varies.

PSI—Pounds per square inch is a common measure of pressure. Unless specified as absolute it is gauge pressure or the measure of pressure above atmospheric pressure.

RELATIVE HUMIDITY—A measure of the moisture content of the air. Expressed as a percentage it is the ratio of the weight of water vapor present to the weight which the same volume of air could hold at the same temperature. When this maximum is reached the air is said to be saturated and the moisture condenses out as visible droplets (steam or fog) and the relative humidity is 100%.

RELIEF VALVE—A valve which protects a gas system from dangerously high pressures. It opens to relieve pressures which are considerably in excess of maximum normal operating pressures.

SOLENOID VALVE—A gas valve which is opened or closed by a solenoid (electro magnet) which is built into the valve mechanism. In a normally closed type the valve is opened by the solenoid but closed by a return spring and held closed by the pressure upstream of the valve.

STATIC PRESSURE—A measure of air pressure usually expressed in inches of water column (WC).

TEMPERATURE RISE—The difference between ambient temperature and drying air temperature.

VAPORIZER—In an LP system the vaporizer is a heat exchanger where heat is supplied to change the liquid fuel into vapor ready for combustion.

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QUESTIONS AND PROBLEMS

1. Explain the need for crop-residue disposal.
2. Explain the differences in design and operation of the different types of crop-residue disposal machines.
3. Give the advantages of hammer feed mills, and explain the grinding operation.
4. Define farm crop dryers.
5. Make an outline showing the various types of farm crop dryers.
6. Explain the function of a heat exchanger.
7. Explain the design differences between fans used with farm crop dryers.
8. Explain the effect of temperature and air flow on the rate and uniformity of drying crop products.
9. List the fan laws.

LABORSAVING EQUIPMENT

24

The handling of farm products such as wheat, oats, milo, shelled and ear corn, bales of hay, and manure is a tiresome job if done with manual labor. Power-operated equipment is now available whereby manual labor is often reduced to the operation of a power unit such as a tractor. Laborsaving equipment for the farm consists of elevators, power hoists, power loaders, wagon unloaders, transport mixer-feeders, post-hole diggers, and brush saws. In addition to these, there are laborsaving gadgets of various kinds too numerous to mention here.

ELEVATORS

In general the elevators used on the farm may be classified as *portable elevators* and *stationary elevators*.

Portable Elevators. The portable elevator makes the farmer's life easier and farm work faster and helps to solve labor shortages. The portable elevator is designed so that it can be moved easily from one location to another. Plans for building homemade portable elevators can be obtained from the extension services of many states. Many different sizes and types are being manufactured. There are three types of portable elevators: the *chain drag-flight* type, the *auger* type, and the *blower* type.

Chain Drag-flight Elevator. The *chain drag-flight* type (Fig. 24-1) is available in lengths ranging from 16 to 50 feet. The trough may be narrow and V-shaped, using a single chain, or it may be as wide as 20 inches with a chain on each side of the chute to support each end of the

drag flights. The wide types have a great range of applications. They can be used to elevate various types of loose grain, ear corn, and bales of hay. The elevator chute should be well braced and trussed to prevent sagging and twisting when long lengths are used.

Two types of hoppers are available for use with the drag-flight elevator: the *trapezoidal-shaped* hopper, which requires that the grain be scooped into it, and the trailer-wagon box, which has a narrow opening to let the grain pour into the hopper. The long *rectangular-folding*-type

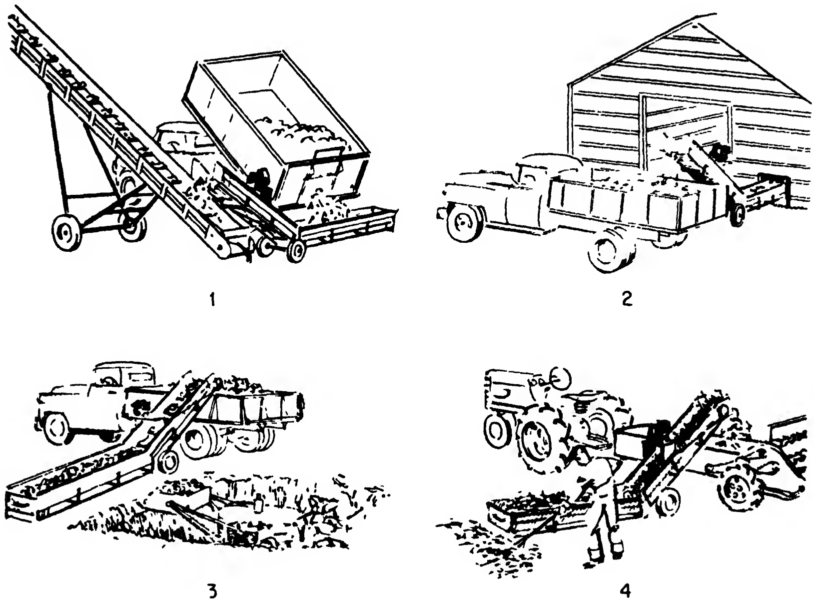

Fig. 24-1. Showing four applications of chain drag-flight portable elevators: 1, conveying ear corn from trailer to barn; 2, conveying material from bin to truck; 3, loading truck; 4, loading manure spreader.

hopper is suitable for handling crop products that are unloaded on a wide-bed scale or where the entire endgate is removed. The front of the truck or trailer can be tilted to let the crop product flow into the hopper. A spout is provided at the top end of the elevator to guide grain into the bin.

Where long, heavy portable elevators are used, a special derrick lifting arrangement (Fig. 24-2) enables one man to raise the long chute to any height desired. The derrick is mounted on pneumatic-tired wheels. When the chute is lowered, the complete elevator can be trailed behind a tractor or truck. The average angle for satisfactory operation varies from approximately 20 to 45 degrees. Greater angles can be used, but they reduce the capacity of the elevator.

Auger Elevators. The *auger*-type portable elevator is simple in construction, as it consists of a long enclosed section of a screw conveyor (Fig. 24-3). The lower end is not enclosed; when the elevator inserted into a pile of grain, the exposed part of the revolving auger automatically picks up the grain and conveys it to the other end. The auger conveyor, however, is suitable only for elevating and conveying grains and seeds.

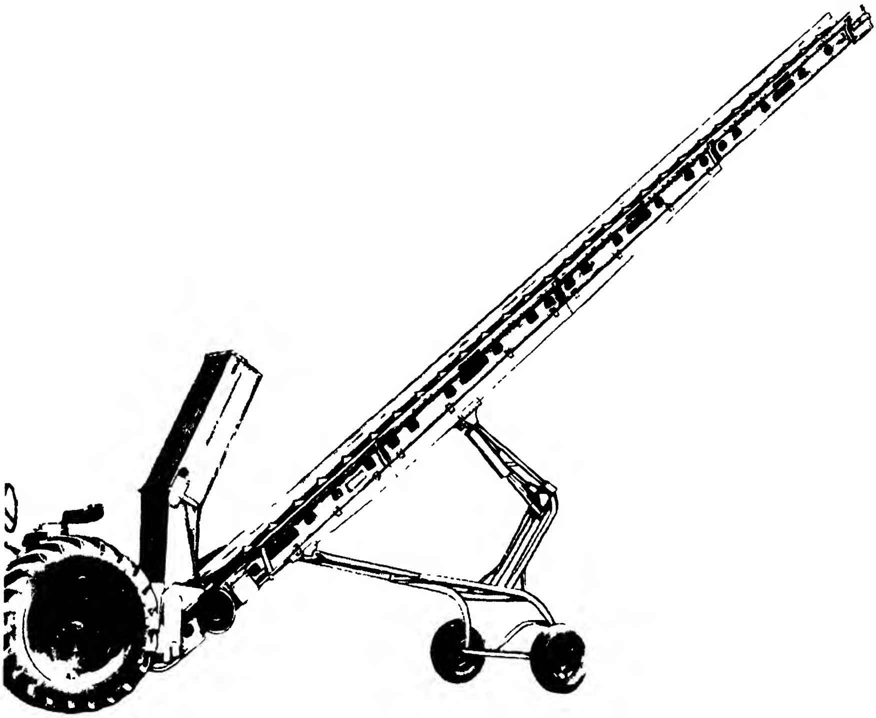

Fig. 24-2. Semi-tractor-mounted portable chain drag-flight elevator. (*Kewanee Machinery & Conveyor Co.*)

Both the chain drag-flight and the auger-type portable elevators can be operated by small electric motors, by gasoline engines, or from the tractor power take-off.

Air Elevators. The blower-type elevator is useful where large quantities of grain are handled. Blowers have been designed so that the grain passes through the fan housing on a cushion of air without being hit and cracked by the fan blades. Figure 24-4 shows a blower elevator. The grain is dumped from the truck into the blower hopper, from which it is fed into the stream of air. Small blowers are attached to the truck body and driven by a special power take-off. Grain blowers will elevate from 300

to 1,200 bushels of grain per hour to heights of 25 to 30 feet. A 5-horsepower electric motor has sufficient power to operate the average-sized blower. Figure 24-5 shows a tractor-mounted suction-blower elevator that can be used for unloading cotton from trailers or for the loading of trailers from piles of cotton. Silage blowers were described under Forage Harvesting Equipment.

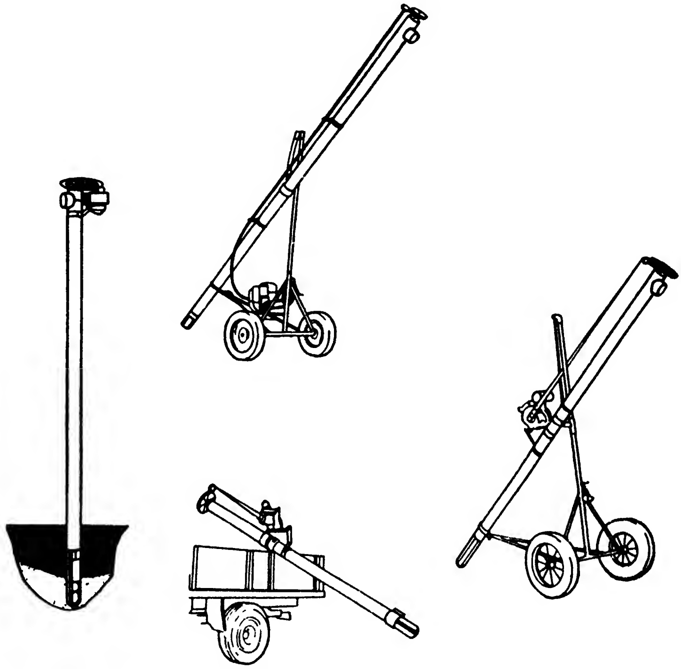

Fig. 24-3. The auger-type portable elevator can be operated at almost any angle. The auger is driven from the top end by a gasoline engine or electric motor that can be mounted at various locations as shown. (*Wyatt Mfg. Co.*)

Stationary Elevators. When a farmer has a barn with bins for the storage of small grain and corn, he may wish to install a permanent bucket-type elevator such as that shown in Fig. 24-6. Several types can be obtained, but this is typical. The elevator chute is set vertical or almost vertical, so that cups attached to chains can be used to elevate the grain.

TRUCK AND WAGON HOISTS

When trucks or trailer-wagon loads of material are to be unloaded into elevator hoppers, time and labor can be saved by the use of hoists for tilting the vehicle. Mechanical hand, power-operated, and hydraulically

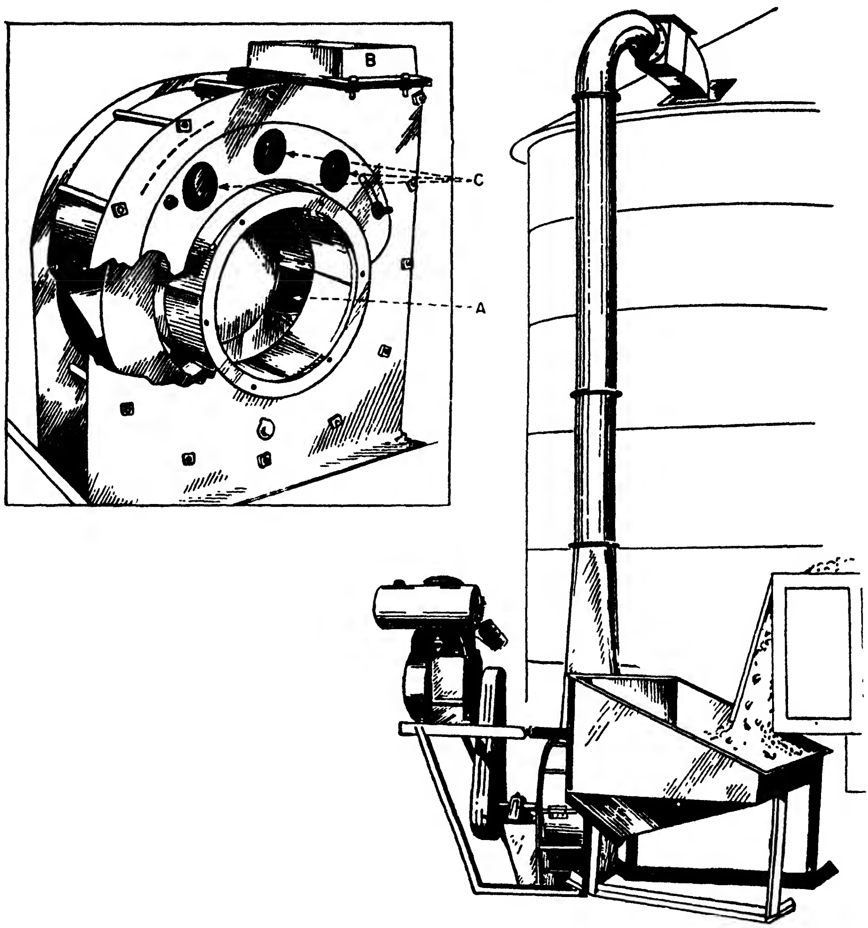

Fig. 24-4. Blower-type elevator unloading grain from truck to bin. *Inset:* fan housing with auxiliary air ports.

operated hoists are available. Hydraulic cylinders may be used to tilt either the body of the truck only (Fig. 24-7) or the entire truck.

TRACTOR–HITCH UTILITY CARRIER

Figure 24-8 shows a carrier rack, or platform, attached to a three-point tractor hitch. The platform can be lowered to the ground and raised to truck- or trailer-bed height. Barrels, rolls of wire, and many heavy machines and tools can thus be lifted and transported on the farm without much manual lifting.

POWER LOADERS

The tractor-mounted power loaders are also called *manure loaders.* They received this name, no doubt, because this type of machine was developed largely for the loading of manure. It has, however, many other uses. It can be used to load on trucks bales of cotton, baled hay, dirt,

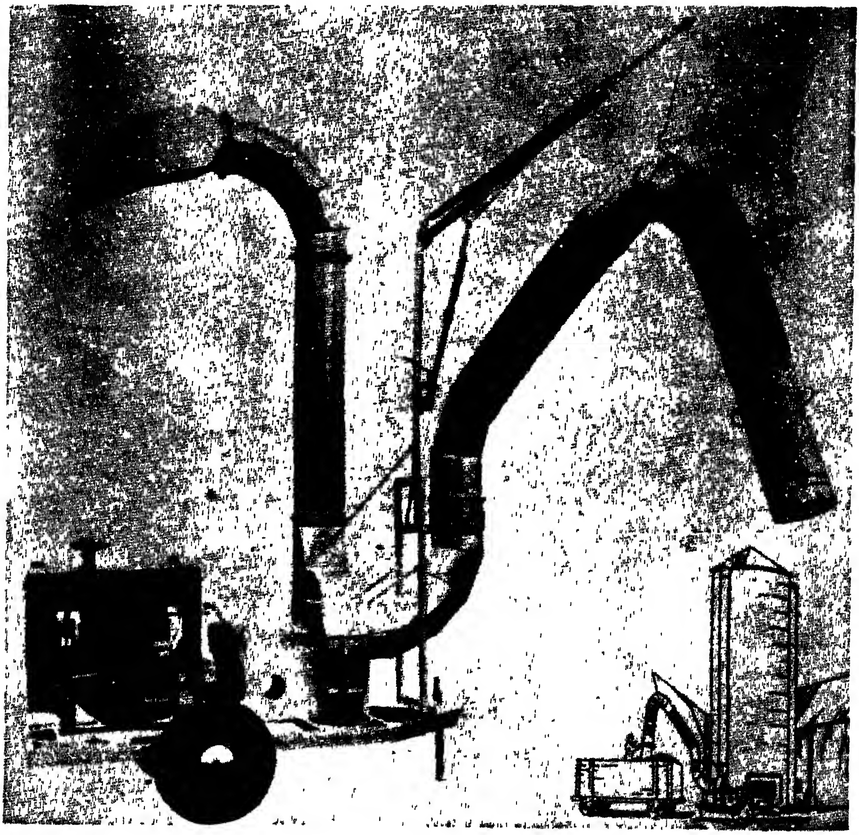

Fig. 24-5. Portable suction-blower elevators can be used either to unload or to load trucks and trailer wagons. (*Pieck Vacuum Blower Co.*)

gravel, sand, and many other materials (Fig. 24-9). If manure is tc be loaded in a barn where the ceiling is low, a loader should be selected with the lifting beams arranged so they do not rise up and hit the ceiling before the scoop has been lifted high enough to dump into the manure spreader. The loader shown has a frame linkage that permits the load being lifted above the highest part of the machine.

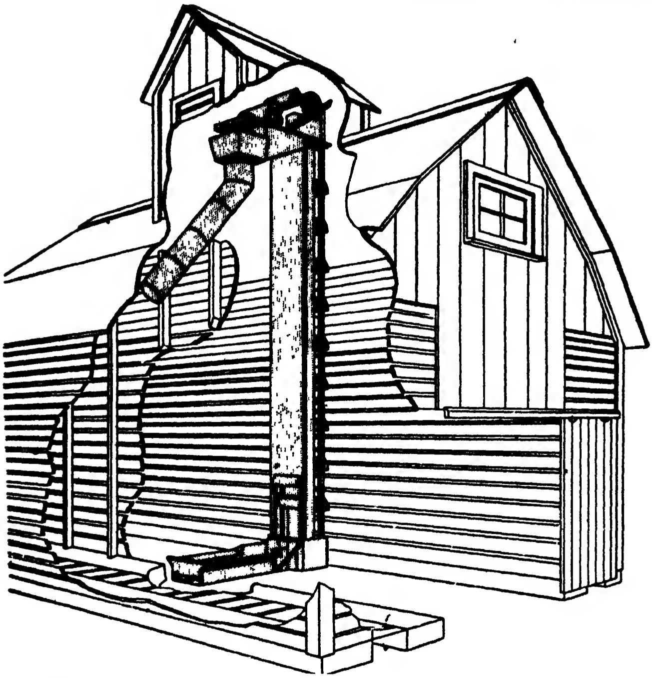

Fig. 24-6. Bucket elevator for small grain installed in driveway of barn. (*King and Hamilton Co.*)

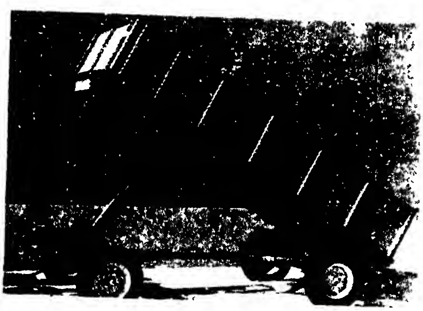

Fig. 24-7. A hydraulic hoist is used to tilt trailer or truck box so material will flow out by gravity. The hydraulic remote-control cylinder is operated from the tractor. (*Deere & Co.*)

Most power loaders use hydraulic power for lifting the scoop, but a few use mechanical winches or a block and tackle. Figure 24-10 shows several methods of mounting power loaders on tractors.

The scoop or bucket can be removed and a special platform attached to the boom frame and the lift then used to harvest fruit and do many

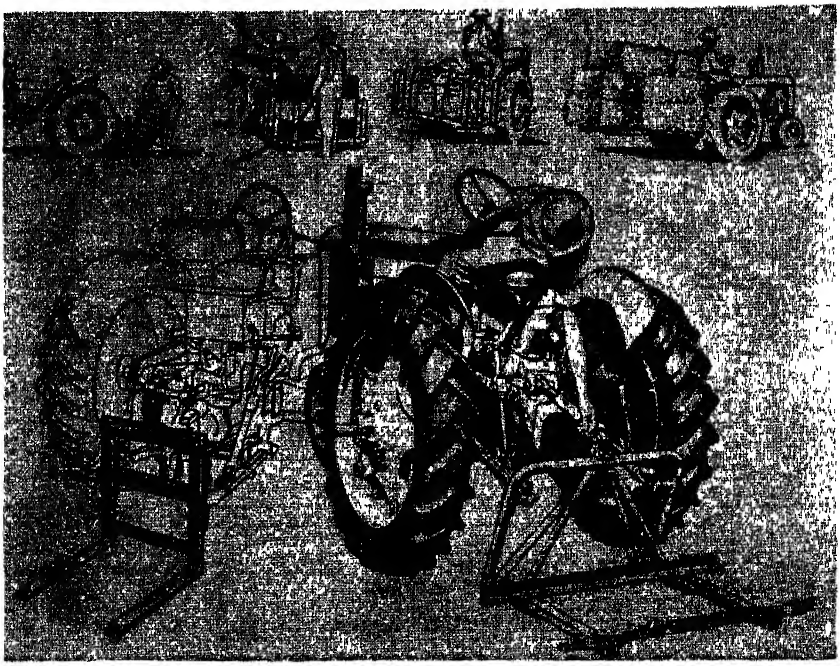

Fig. 24-8. Carrier racks or platform lifts can be attached to three-point tractor hitches for lifting heavy articles. (*Deere & Co. and J. I. Case Company.*)

other aboveground tasks that otherwise would require a ladder. Different types of scoops, bulldozer blades, hay forks, and other attachments are available for power loaders.

Baled-hay Pickup Loaders. This type of loader was described under Hay Harvesting Equipment.

TRUCK, WAGON, AND BIN UNLOADERS

Power-operated truck and trailer-wagon unloaders save time and labor in unloading chopped silage into the blower at the silo. Generally, five methods can be used to unload vehicles, namely, *fence wire, movable front endgate, movable bottom, tilt body*, and *air*.

The *fence-wire* method consists in laying a section of wire fencing on the floor of the trailer box and extending it up over the front end of the trailer where it is attached to a wood or steel bar. To unload, a cable is attached to the bar which extends back over the load to a truck or tractor. As the bar with the wire attached is pulled backward, the chopped material is rolled out the rear of the box. The disadvantage of this method is that the front part of the load will roll up on top of the rear part of the

load and fall in amounts too large for the blower to handle. A man with a fork is required to distribute the material.

The *movable-front-endgate* unloading method consists of a false front endgate which is drawn backward as cables attached to it are wound

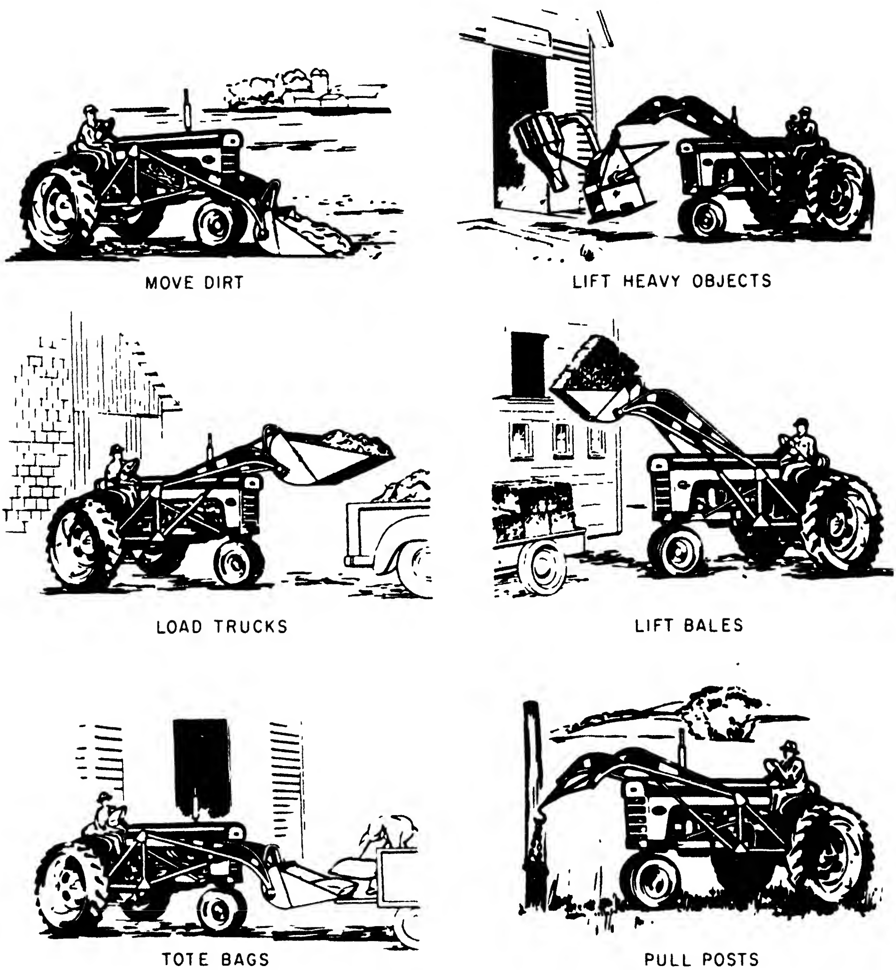

Fig. 24-9. Showing some of the jobs a power loader can do.

around a power-driven shaft at the rear of the box. Sliding green, heavy silage over the floor of a trailer box requires considerable power.

Conveyor Unloaders. A canvas or metal link conveyor belt is installed over the solid bottom of the wagon box (Fig. 24-11). As the belt moves back, the load is moved with it. Figure 24-12 shows a conveyor web that con-

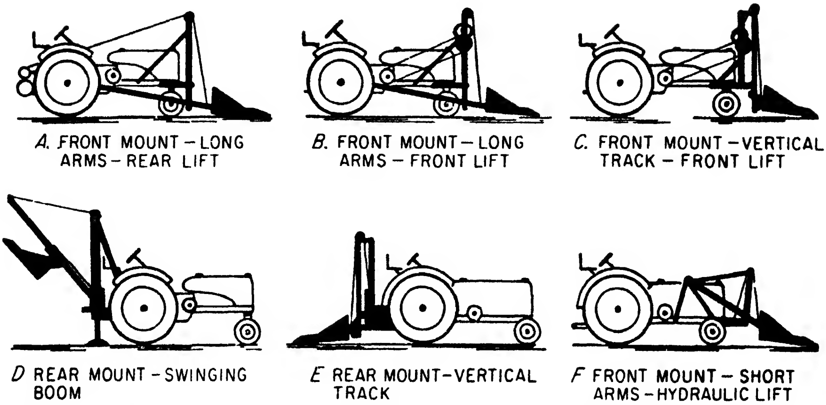

Fig. 24-10. Methods of mounting power loaders on tractors. (*South Dakota Agr. Expt. Sta. Bul.* 378.)

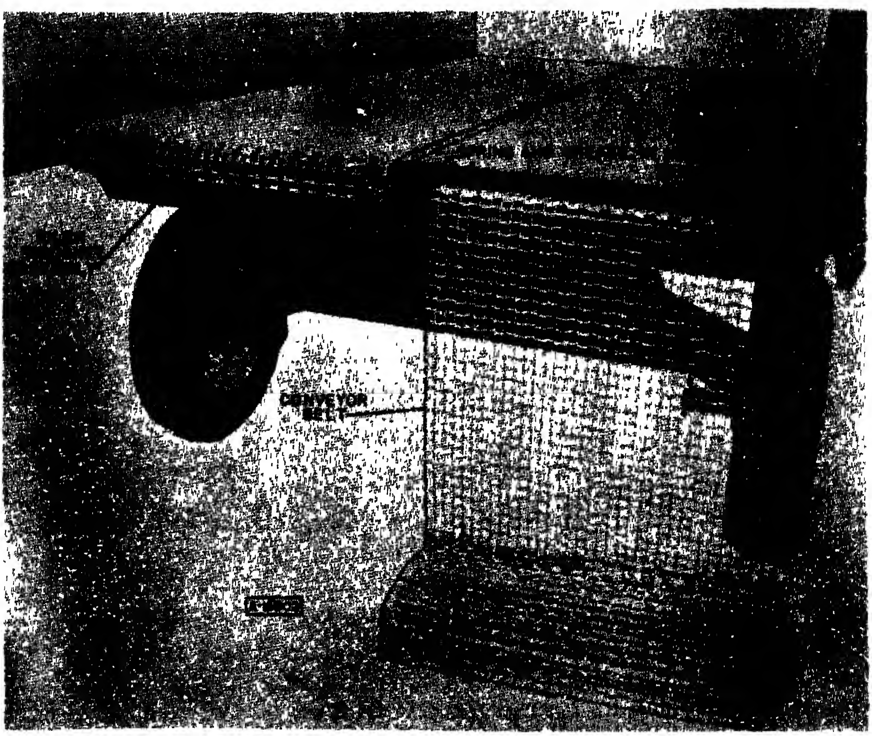

Fig. 24-11. Power-driven steel-link conveyor belt that moves the material out the rear end of the wagon box. (*J. I. Case Company.*)

sists of two steel chains with steel angle crossbars. The load is moved by the crossbars as the conveyor moves to the rear of the box. This is the same type of conveyor that is used on manure spreaders (Chap. 15).

The conveyor is driven by a gear-reduction box powered by an electric motor, gasoline engine, or tractor power take-off.

The *tilt-body* method consists of lifting the front end of the box or entire vehicle. When the rear endgate is removed, the material slides out by gravity (Fig. 24-7). Dry grain and ear corn will readily flow when the box is at 40 to 45 degrees with the horizontal. Wet material, such as silage, requires a greater angle for the body to clear itself.

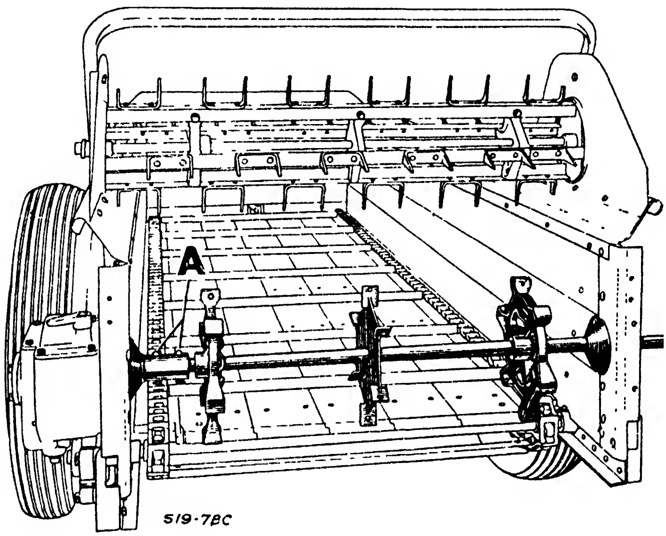

Fig. 24-12 Power-driven web apron conveyor for unloading manure from box.

The *air* unloading method shown in Fig. 24-5 sucks the material out of the box and blows it into the silo or bin.

Bin Unloaders. A chain drag-flight type of bin unloader is shown in section 2 of Figure 24-1. The long horizontal unit can be projected into the bin, or it can be set under a spout on the side of the bin. Small and medium-sized auger portable elevators can be projected into the bin and the grain unloaded, or an extension section can be used to unload bins.

TRANSPORT MIXER–FEEDERS

Where large numbers of livestock are being fed, the use of a truck-mounted or trailer-type transport mixer-feeder will save countless hours

of scoop labor in handling the feed. Chopped roughages and ground grains are mechanically loaded into a specially constructed, inverted semi-trapezoidal box equipped with a power-driven agitator and a mechanical power-driven unloader elevator (Fig. 24-13). The feed is mixed in transit, and as the outfit is driven along the feed troughs, the feed is mechanically elevated and delivered directly into the troughs. The agita-

Fig. 24-13. A trailer-type bulk-feed mixer wagon operated by the tractor power take-off. (*Knoedler Manufacturers, Inc.*)

tor and elevator on the trailer mixer-feeders are usually driven from the power take-off of the tractor that tows the machine.

POWER POST-HOLE DIGGERS

The digging of post holes to build fences about the farm and pasture is slow, hard work when done by hand. Power-driven post-hole diggers make the job easier and many times faster. A power-driven post-hole

digger with power pressure and lift can dig a standard post hole in a few seconds. The majority of post-hole-digging attachments are mounted on the rear of the tractor so that the power can be obtained from the power take-off (Fig. 24-14). The best power post-hole diggers have an arrangement whereby pressure can be applied to force the auger into the soil and a power-lifting device used to lift the auger from the hole.

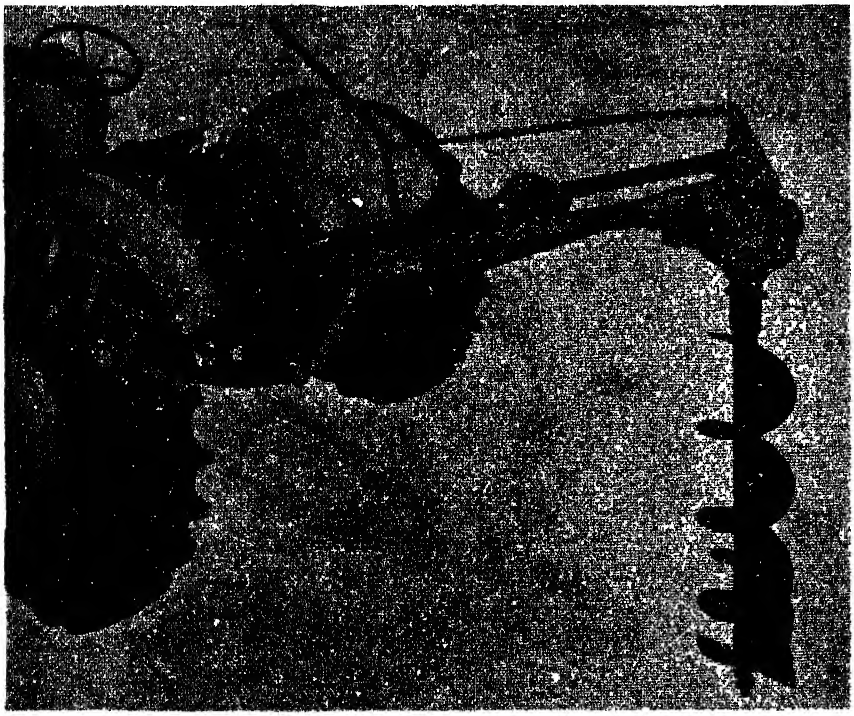

Fig. 24-14. Tractor-mounted power-take-off-driven post hole digger. (*Ford Motor Co., Tractor and Implement Division.*)

BRUSH CUTTING EQUIPMENT

The destruction of small to medium-sized brush can be accomplished with heavy-duty rotary beaters, rolling cutters, and the horizontal-rotating-knife-type cutter-shredders (Fig. 24-15). These machines were described under Crop-processing Equipment.

Circular saws mounted on tractors and on two-wheel carts are suitable for sawing down larger brush and trees. A small gasoline engine furnishes

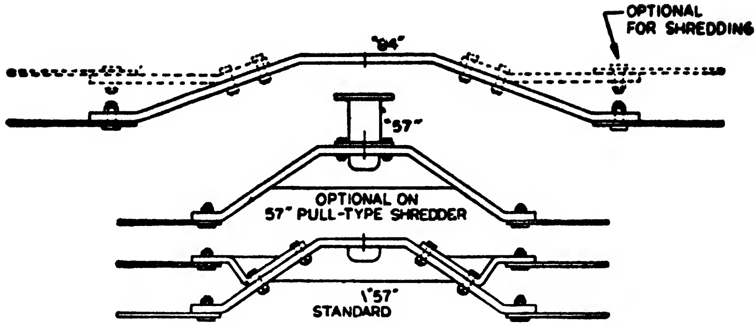

Fig. 24-15. Types of horizontal rotating knives used for shredding medium-size brush.

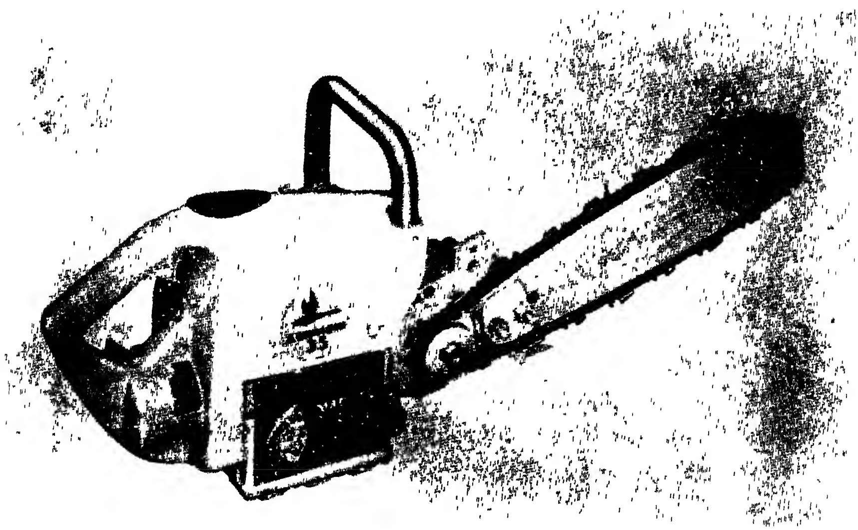

Fig. 24-16. Chain saw suitable for cutting trees and brush. (*McCulloch Corp.*)

power for operating the saw. Hand-held chain saws are useful in cutting timber (Fig. 24-16).

AIR COMPRESSORS

As most farm equipment and tractors are equipped with pneumatic tires, every farm should have a small air compressor (Fig. 24-17). Tires can be easily inflated, and with an air-jet tip, radiators can be cleaned and dirt and dust blown out of hard-to-get-to places.

SPECIAL TRAILERS AND WAGONS

Trailers and wagons have been developed to handle special farm products, such as grain, chopped forage, machine-harvested cotton, and livestock. Figure 20-13 shows a large trailer frame covered with steel

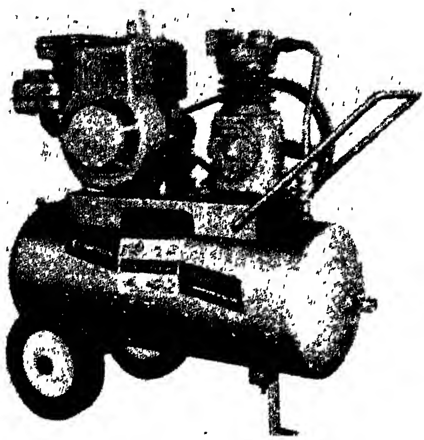

Fig. 24-17. A small air compressor that can be operated by either a gasoline engine or electric motor. (*Champion Pneumatic Machinery Co.*)

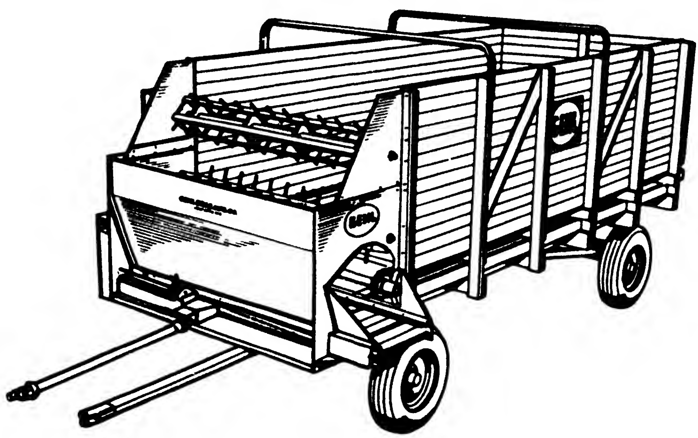

Fig. 24-18. A self-unloading chopped forage trailer wagon.

mesh wire designed for hauling several bales of machine harvested cotton from the farm to the gin. Figure 24-18 shows a trailer wagon equipped with conveyor and beaters that are driven by the tractor power take-off. The box unloads itself.

Almost every farm and ranch that has livestock of any kind has some type of truck or trailer for transporting the animals. Many are made at local shops, and design varies with the fancy and whims of the individual.

REFERENCE

Push-button Farming, *Farm Impl. News,* 74(11):40–41, June 25, 1953.

QUESTIONS AND PROBLEMS

1. Explain the differences between the various types of elevators.
2. Give several uses of power loaders.
3. Describe the various types of unloading equipment for trucks and trailer-wagons.
4. What are the advantages of using a transport mixer-feeder?

SELECTION OF FARM MACHINERY

25

After studying the various individual farm implements and their construction features, it is well to consider some of the important items that apply to all implements in general. These points or qualities that a machine may have or that it may lack are abstract in a way, yet they are fundamental in their bearing on the quality of the machine. They are factors that will enable the student to judge a machine better; they will call to his attention the points to look for and may have an important influence on selecting one machine over another.

Trade-mark. The standard definition of a trade-mark is as follows: *Trade-mark* is a distinguishing mark, device, or symbol affixed by a manufacturer, merchant, or trader to his goods in order to identify them as his goods and to distinguish them from the goods manufactured, sold, or dealt in by others. Most countries give special statutory protection to such trade-marks when they are registered according to law. This registration gives the owner of the trade-mark exclusive right to its use.

The importance of the trade-mark in the selection of farm machinery lies in what it stands for. A manufacturer spends many years and much money in building a reputation and establishing his trade-mark. After the reputation and trade-mark are thoroughly established and well known among the trading world, he will continue to try to maintain the same standards. It is not possible to judge a machine by its appearance or to determine whether good materials are used in its construction simply by looking at it. Therefore, if it bears the trade-mark of a firm that has a good reputation, it is fairly certain that the manufacturer of such an implement will stand behind that particular piece of machinery. If any

defect occurs within a reasonable length of time, the firm will make it good. In other words, then, we may say that the trade-mark of a machine is a guarantee of what lies beneath the paint. Look well to the builder of your machine when you are judging and preparing to invest.

Trade Name. The trade name is the name by which an article is called or the name given by a manufacturer to an article to distinguish it as one produced by that company. It is entirely different from the trade-mark. A trade name can be registered in the U.S. Patent Office and thus have statutory protection in a manner similar to a trade-mark. A trade name will be found only on one particular type of equipment, such as Farmall for a line of row-crop tractors. A well-known trade name is valuable from a sales standpoint. The use of trade names in the farm-equipment industry is being abandoned in favor of model designations.

Models. Models in farm equipment may indicate a type of machine, a size, an improvement or new design of an old machine, a special-purpose machine, or a combination of one or more of these features. Model designations may be by a series of numbers or letters or a combination of both numbers and letters. For example, a combine model may be given as SP-12, which indicates that this particular machine is self-propelled and cuts a 12-foot swath. In another case, a tractor-mounted planter is listed as a 34-400 two-row planter. The 400 indicates the size of the tractor. In the number 34, the 3 indicates a two-row planter or cultivator while the 4 indicates a four-row planter or cultivator. Each manufacturer has his own special system of designating models. Farm-equipment models are not dated on an annual basis as are automobiles; consequently, when a machine is needed, there is no necessity to wait for next year's model.

Repairs. Before considering the purchase of any machine, it is well to look into the source of repairs. Can repairs be made near at hand, or will it be necessary to send several hundred miles away? No farm implement has yet reached the stage of perfection where it will not break, wear out, or meet with accidents; therefore, it will need repairs. Many times the saving of a crop depends upon the speed with which repairs can be completed. If breakdowns occur in the midst of plowing, planting, or harvesting, they may cause so much delay that the crops will be lost. The larger implement companies maintain repair supplies at many points so that they can render quick service to every part of the country. The machine should be examined to see whether the various parts are accessible for making repairs when needed. Provision should be made in all implements for taking up the wear of bearings and gears. Look well to the source of supplies before buying a machine.

In making up the order for repair parts that are needed, be sure to secure the following information:

1. The name and address of the manufacturer.
2. Trade name, model number, year made or purchased.
3. Number of the part wanted.
4. If the number of the part cannot be determined, then get the numbers of the parts with which it works.

Keep the pamphlets that are furnished with the machine, especially the one containing the repair parts lists. When repair parts are needed, the part numbers and their description will be found in the list of parts. From the standpoint of repairs, it is economical to standardize on a single line of equipment.

Design. Design is the arrangement of the parts to show the difference of make-up in machines of the same type. Manufacturers may put out the same line of implements, but they will not be exactly alike. It is this difference of the arrangement of the component parts that makes up the design of the machine. In studying the general construction of the machine, keep in mind the number of castings, gears, points of wear, bearings, ease of lubrication and adjustment. Wherever possible, gears should run in a sealed oil bath. Provision of safety devices should be carefully considered. Be sure there are shields over power take-off drive shafts. In general, does the machine have a finished appearance and style without sacrificing strength and performance?

Ease of Operation. Many implements that look well are found to require an unnecessary amount of power and labor to make them operate successfully. Of course, it is not always feasible to have the machine demonstrated to see if it will operate easily; nevertheless, such things should be considered in the selection of the machine. The ease of operation may simply depend upon the correct adjustment. It is not an uncommon thing for a farmer to purchase an implement, take it home, and, after attempting to use it, condemn the machine because of its hard operation. He may go so far as to take it back to the dealer and ask for his money back. If the dealer is a good one, he will usually take the machine out, have the farmer go along, make the necessary adjustments, and see that the machine is running perfectly before he turns it over to the farmer.

Power and hydraulic lifts have taken the place of the manually operated levers. When the machine has once been properly adjusted, little effort is required of the operator other than the steering and turning of the machine.

Ease of Adjustment. In the selection of farm equipment, careful study should be made of the methods for adjusting the various parts. Devices designed to simplify adjusting the equipment are time and labor savers. The owner's or operator's manual should be studied thoroughly to understand the method of adjusting the equipment as planned by the designer and the test engineer. Many operators of farm equipment are not inclined

to take sufficient time to make slightly needed adjustments. The author suggested some adjustments to a farmer who was operating a harvesting machine. His reply was, "I know it will do better work if I make the changes, but I'm in a hurry to get my crop out." His crop losses were, no doubt, many times greater than the value of the thirty minutes' time it would have taken to make the adjustments. Too many operators take the "I'm in a hurry" attitude about adjustments.

Adaptability to Work and Conditions. There are many implements on the market which are not adaptable to every condition. A maohine may work in one locality and be an absolute failure in another because it is adapted to certain soil conditions or types of crops grown. To take an example: Tools built for the Southeastern and Gulf coast states are not suitable for use in the Southwestern states, New Mexico or Arizona, because of the difference in climate, which influences the methods of preparing the seedbed, planting, and cultivating.

Quick Change of Units. The time and labor required to dismount one unit and mount another are important considerations in selecting farm equipment. Some lines of equipment are built in unit packages and are designed so that changes can be made in a few minutes from a plow to planter, from planter to cultivator, or from one unit to another for all the units supplied. There are other lines that require one or more days to change from planter to cultivator and the same time to change back to planter.

Most integral-tractor-mounted equipment is designed for a certain make of tractor and cannot be used on any other make.

Maneuverability. As a general rule, tractor-mounted equipment is provided with power and hydraulic lifts. The units can be lifted and the tractor maneuvered almost as though no equipment was attached. When trailing equipment is attached to the drawbar of a tractor, turns cannot be made so sharply as with mounted equipment. Extended and swinging drawbars are an aid for short turning. Maneuverability problems are increased when a trailer is drawn behind a trailing-type harvester. The maneuverability is greatly reduced when machines are mounted in front of row-crop tractors. The small wheels sink into loose soil, drop into shallow ditches and furrows, and the tractor is difficult to turn.

Comfort. As the operator of power equipment must spend days upon days riding upon it, the comfort and safety of the seat should be considered. A comfortable seat should be supported with shock-absorbing devices. The seat should be stable and adjustable to suit different-sized individuals.

Safety. In the selection of farm power equipment, the safety provisions for both the operator and the machine should be thoroughly checked. All

power take-off shafts should be provided with shields. Snap clutches should be installed to protect the machine in case of plugging.

Other Factors. Other factors to keep in mind in the selection of farm equipment are the power requirements, cost of operation, initial cost, years of service expected, and whether the purchase of the equipment is economical in relation to the size of the farm and the work to be performed by the equipment.

REFERENCE

Farm equipment manufacturers' literature.

QUESTIONS AND PROBLEMS

1. Explain the difference between a trade-mark and a trade name.
2. Discuss methods of designating models in farm equipment.
3. Make up an order for repair parts for a plow, a planter, a combine.
4. Discuss the importance of design in selecting farm equipment.
5. Discuss the need for considering maneuverability and ease of operation and adjustment in selecting farm equipment.
6. Explain the value of having equipment in which the units can be interchanged quickly.
7. Enumerate and discuss the various safety rules in operating farm power equipment.

ECONOMICS AND MANAGEMENT OF FARM EQUIPMENT

26

Generally, the size and type of farm equipment used by a farmer are closely related to the size of the farm in acres, and the kind of crop grown.

The 1959 Census of Agriculture defines a farm in the United States as: "Each place operated as a unit of 100 or more acres from which the sale of agricultural products totaled $50 or more, as well as each place operated as a unit of less than 10 acres from which the sale of agricultural products totaled $250 or more."

This definition of a farm places farming in the United States on a productive business-operation basis rather than the old idea of farming for a living.

Butz[1] states that American agriculture has had three great revolutions and lists them as follows:

> The first great revolution came in the middle of the 19th Century, when we began to substitute animal energy for human energy.
>
> The second great revolution began in the 1920's with the substitution of mechanical energy for animal energy.
>
> The third revolution is the undergirding of agricultural production and marketing with vast amounts of science, technology, and business management.

[1] *U.S. Dept. Agr. Yearbook*, p. 380, 1960.

> The modern commercial farm resembles a manufacturing plant in many respects. The large amount of equipment in use on the farm represents a substitution of capital and machinery for labor.
>
> This development obviously calls for a high level managerial capacity. It is more difficult to manage the modern commercial farm successfully than it is to manage the family-sized manufacturing concern, grocery store, or foundry shop in the city.

The successful commercial farmer must determine what farm equipment meets his needs according to his acreage and crop. There are many factors to consider.

Matching Equipment to Farm Needs. Before buying farm equipment, a farmer must decide which make, size, and type of machine will be the most efficient for both the farm and the equipment. It is a difficult job to match equipment needs to meet the farm needs. The farmer must decide whether or not his acreage, production, and especially his income are sufficient to justify the purchase of expensive equipment.

He must decide whether it is more economical to own the equipment and furnish the labor and supplies for its operation or to hire the equivalent services through custom work.

Ownership Essentials. When a farmer buys equipment for his farm, he must assume a number of expense items. These can be divided into fixed and variable costs.

The fixed costs include:

1. Original purchase
2. Depreciation
3. Interest on investment
4. Taxes
5. Repairs
6. Insurance
7. Shelter

The variable costs include:

1. Fuel (for self-powered units)
2. Lubricants
3. Labor
4. Tractor, fuel, oil, and grease

Figure 26-1 shows the relative importance of the various total fixed and variable costs when plowing with a four-plow tractor and four 16-inch bottoms.

Purchasing Equipment. Equipment for single-crop farming, such as cotton, corn, or small grain, is less expensive than that required for mixed-crop farming of cotton and grain sorghum, wheat and corn, and combinations of other crops.

A cotton farm requires tractor power, plows, harrows, planters, weed- and insect-control equipment, and harvesters. If corn is included in the

operation, additional harvesting equipment is required. Small-grain crops require special seeding and harvesting equipment that is not needed for the production of cotton. Some equipment is a common requirement for most crops, such as the power unit, plows, and harrows. The combine with adjustments and attachments can be used to harvest a number of crops. The cotton picker and the corn picker are limited in use to single crops.

The retail prices of farm equipment are not given here because the prices vary from one section to another as the result of transportation charges and state sales taxes.

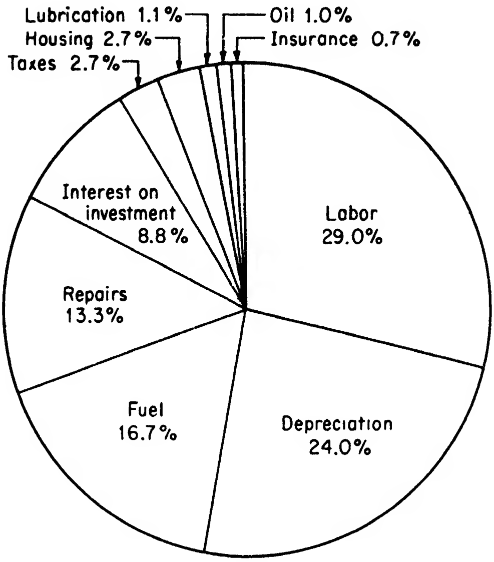

Fig. 26-1. The relative importance of each item of cost when plowing with a four-plow tractor and four 16-inch mounted shares. (*Kans. Agr. Expt. Sta. Bul.* 417, 1960.)

Table 26-1, however, shows the cost per hour of using various types of farm machines. The table also shows the approximate years and hours of service for the basic types of equipment used on farms.

Cost of Use of Crop Machines. The depreciation cost for the machines shown in Table 26-1 has been calculated on a straight-line basis, using a life based on whichever occurs first, wearing out or obsolescence. For instance, a grain drill which will be obsolete in 20 years or worn out in 1,200 hours will depreciate one-twentieth of its new cost per year until it is used over 60 hours per year, when it will depreciate one twelve hundredth of its new cost per hour. Depreciation cost can be estimated for a

TABLE 26-1. COST PER HOUR OF USING FARM MACHINES

Per $100 of new cost

Machine	Years until obsolete	Hr. to wear out	Total repair cost, % of new cost	20 hr. per year	Cost per hr. of use per $100 of new cost*					
					40 hr. per year	60 hr. per year	100 hr. per year	150 hr. per year	250 hr. per year	350 hr. per year
Tractor plow	15	2,000	80	$0.600	$0.319	$0.226	$0.152	$0.120	$0.108	$0.103
Tractor disk harrow	15	2,000	30	0.575	0.295	0.202	0.127	0.095	0.083	0.078
Spring-tooth harrow	20	2,000	40	0.495	0.253	0.179	0.115	0.100	0.088	0.083
Spike-tooth harrow	20	2,500	30	0.487	0.250	0.171	0.107	0.082	0.070	0.065
Roller	25	1,500	10	0.432	0.220	0.149	0.118	0.103	0.091	0.086
Soil pulverizer	20	2,000	15	0.483	0.245	0.167	0.103	0.088	0.076	0.071
Endgate seeder	20	800	30	0.512	0.275	0.238	0.208	0.193	0.181	0.176
Grain drill	20	1,200	25	0.496	0.258	0.179	0.149	0.135	0.122	0.117
Corn planter	20	1,200	30	0.500	0.263	0.184	0.153	0.138	0.126	0.121
Field sprayer	10	1,500	30	0.745	0.383	0.262	0.165	0.117	0.105	0.100
Rotary hoe	15	1,500	20	0.573	0.293	0.200	0.125	0.110	0.098	0.093
Tractor cultivator	12	2,500	40	0.662	0.341	0.234	0.148	0.106	0.078	0.073
Rotary cutter	12	2,000	35	0.659	0.338	0.232	0.146	0.104	0.086	0.081
Tractor mower	12	2,000	75	0.679	0.358	0.252	0.166	0.124	0.106	0.101
Dump rake	10	1,500	25	0.742	0.379	0.259	0.162	0.114	0.102	0.097
Side-delivery rake	15	1,500	50	0.591	0.312	0.219	0.145	0.130	0.118	0.113
Tractor buck rake	12	1,500	25	0.657	0.337	0.231	0.145	0.114	0.102	0.097
Hay loader	10	1,200	25	0.746	0.383	0.263	0.166	0.134	0.122	0.117
Forage harvester†	12	2,000	60	0.671	0.350	0.244	0.158	0.116	0.098	0.093
Forage blower	12	2,500	25	0.651	0.330	0.224	0.138	0.096	0.068	0.063
Pickup baler (auto tie)†	12	2,500	40	0.657	0.336	0.230	0.144	0.102	0.074	0.069

TABLE 26-1. COST PER HOUR OF USING FARM MACHINES

Per $100 of new cost (Continued)

Machine	Years until obsolete	Hr. to wear out	Total repair cost, % of new cost	20 hr. per year	Cost per hr. of use per $100 of new cost*					
					40 hr. per year	60 hr. per year	100 hr. per year	150 hr. per year	250 hr. per year	350 hr. per year
Swather	12	1,200	25	0 662	0.341	0.235	0.149	0.134	0.122	0.117
Combine†	10	2,000	40	0.745	0.383	0.262	0.165	0.117	0.088	0.083
Corn binder	10	1,000	40	0.765	0.402	0 282	0.185	0.170	0.168	0.153
Stationary silage cutter	10	1,200	30	0.75	0 387	0.267	0.170	0.138	0.126	0.121
Husker-shredder	10	2,500	25	0.735	0.372	0.252	0.155	0.107	0.068	0.063
Corn picker	10	1,500	30	0 745	0 383	0 262	0.165	0.117	0.105	0.091
Spindle cotton picker	10	2,000	55	0.753	0.390	0 270	0.173	0.125	0.096	0.091
Manure loader	10	2,000	25	0.738	0 375	0 255	0.158	0.110	0.086	0.076
Manure spreader	15	2,500	25	0.568	0.289	0.195	0.122	0.084	0.068	0.063
Feed grinder	15	2,000	25	0 571	0.292	0.198	0.125	0.093	0.081	0.076
Portable elevator	15	1,500	15	0.568	0.289	0.195	0.122	0.107	0.095	0.090
				60 hr. per year	150 hr. per year	300 hr. per year	500 hr. per year	750 hr. per year	1,000 hr. per year	1,500 hr. per year
Wagon gear and box	15	5,000	50	0 196	0 084	0.047	0.039	0.036	0.035	0.033
Tractor	15	12,000	120	0.196	0.084	0.047	0.032	0 025	0.023	0.021

* Based on 4½ per cent of new cost as total annual charge for interest, housing, taxes, and insurance.

† Operating costs such as fuel, oil, grease, wire, twine, etc., not included.

SOURCE: *Agr. Engin. Yearbook*, 1962.

particular machine by applying the life data in Table 26-1 to the chart in Fig. 26-2.

Repair cost has been calculated as a constant cost per hour based on the *life repair cost* divided by the *hours of life*. The above grain drill, with a *life repair cost* of 25 per cent of the new cost, would have an hourly repair cost of one forty-eight hundredth of the new cost. Repair

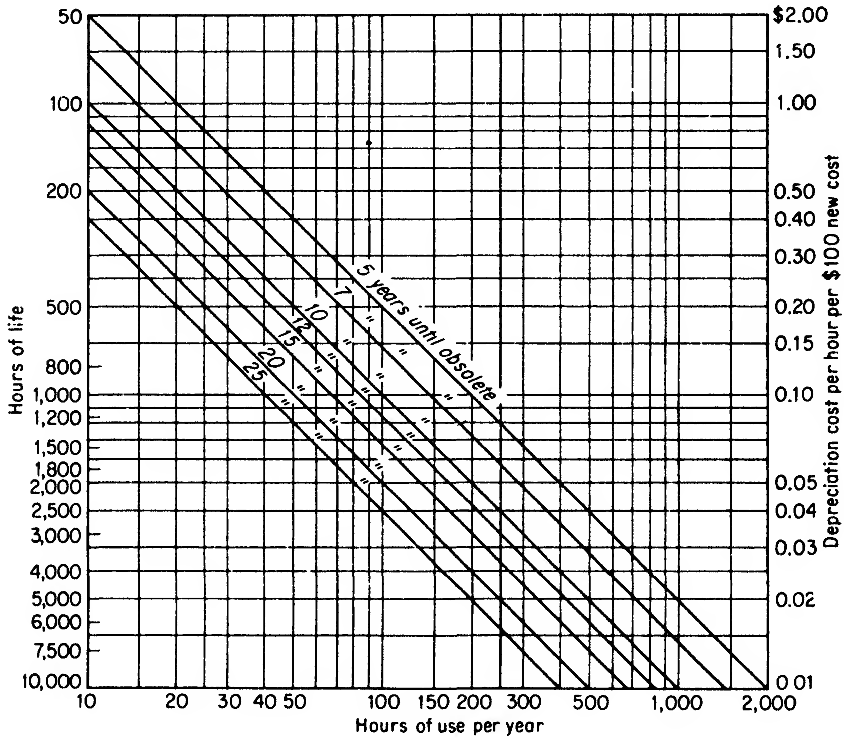

Fig. 26-2. Depreciation cost of farm machines. To find depreciation cost per hour per $100 new cost: 1, locate intersection of hours of use per year with hours of life; 2, locate intersection of hours of use per year with years until obsolete; 3, from upper of these intersections move to right and read. (*Amer. Soc. Agr. Engin. Yearbook*, 1962.)

cost can be estimated for a particular machine by applying the life and repair data in Table 26-1 to the chart in Fig. 26-3.

Interest, housing, taxes, and insurance can be grouped together, since the cost of each can be expressed by an annual charge. Annual costs for interest, housing, taxes, and insurance can usually be determined best by considering the specific case. If better estimates are not available, the following costs can be used as typical for farm machines in general:

Interest.............	\$5.00 per year for each \$100 value
Housing............	\$1.60 per year for each \$100 value
Taxes...............	\$2.00 per year for each \$100 value
Insurance...........	\$0.40 per year for each \$100 value

Capacity of Field Equipment. The capacity of a farm machine is the rate at which it can cover a field while performing its intended function or useful work. This is usually figured as the acres per hour a machine will

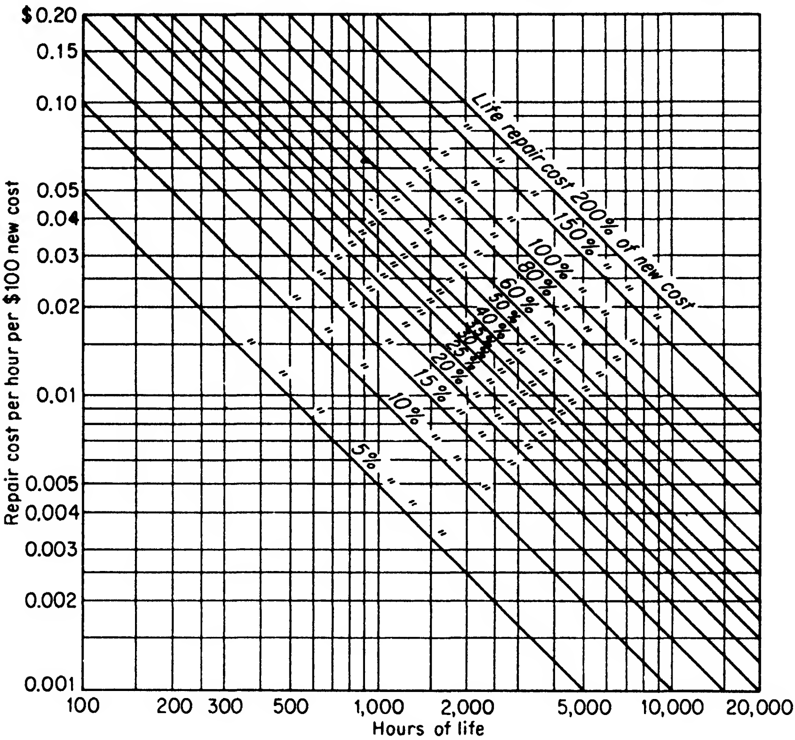

Fig. 26-3. Repair cost of farm machines To find repair cost per hour, locate intersection of hours of life with life repair cost percentage, move to left and read. (*Amer. Soc. Agr. Engin. Yearbook*, 1962.)

cover. The factors involved are the width of useful work and the speed of travel with an allowance for lost time in turning and servicing the machine.

The theoretical field capacity of an implement is the rate it will perform its intended function if it is operated continuously at its rated width. It is the actual acres covered per hour. There is no allowance for loss of time and servicing. The theoretical field capacity is calculated by multiplying the forward speed in miles per hour by the operating width and dividing the product by the factor 8.25. The factor is found by

dividing the number of square feet in an acre by the number of feet in a mile, or $43{,}560 \div 5{,}280 = 8.25$. This gives a dimensionally consistent equation.[2]

The *effective field capacity* of an implement is the average rate at which it covers a field expressed in acres per hour. This includes an allowance for loss of time in turning and servicing. Figure 26-4 shows a chart from which the effective capacity of machines can be read.

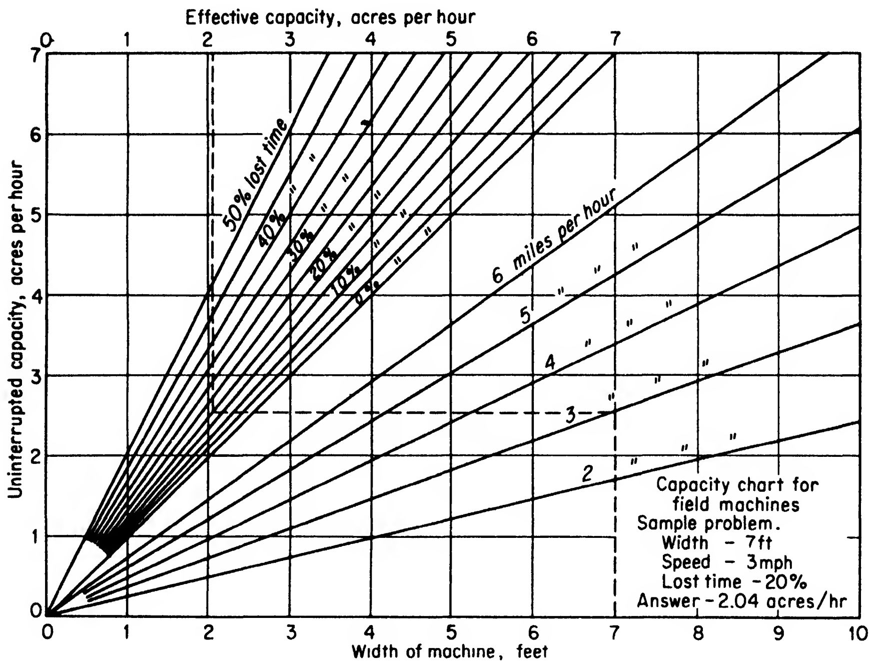

Fig. 26-4. Chart from which can be read the capacity of field equipment for various widths, speed, and percentage of lost time, without making calculations. (*Amer. Soc. Agr. Engin. Yearbook,* 1962.)

The effective field capacity of a machine in acres per hour is determined by dividing the product of the speed, in miles per hour, and the rated width by 8.25 and multiplying the result by the field efficiency expressed as a decimal fraction.

The *field efficiency* of a machine is effective field capacity divided by the theoretical field capacity and multiplied by 100 to express it as a percentage. This field efficiency of a machine is always less than 100 and

[2] Kenneth K. Barnes and Paul E. Strickler, Management of Machines, *U.S. Dept. Agr. Yearbook*, pp. 346–354, 1960.

is influenced by various factors involved in the effective capacity. The field efficiency of a plow may have a range of 74 to 84, disk harrow 77 to 90, grain drill 60 to 78, mower 77 to 85, combine 63 to 70, cotton picker and corn picker 55 to 70.

Doubling the size of a machine does not double the theoretical or effective capacity. It may decrease the field efficiency as shown in the data in Table 26-2. The data show that to double the theoretical capacity of a four-row planter it would require a nine-row planter.

TABLE 26-2. IDEALIZED CAPACITIVE PERFORMANCE OF ROW-CROP PLANTERS

Assuming 40-inch rows, 1,200 feet long and a speed of 4.5 m.p.h.

Activity	Distribution of time, min. per acre			
	Field observations		Predictions	
	4-row	6-row	9-row	12-row
Planting	8.22	5 50	4.11	2.75
Turning	0.50	0.50	0.50	0.50
Filling hoppers	1 40	1.40	1.40	1.40
Adjusting, checking, cleaning	0.54	0.54	0.54	0.54
Miscellaneous	0.75	0.63	0.56	0.50
Total	11.41	8.57	7.11	5.69
Capacity summary				
Theoretical field capacity, acres per hr	7.3	10.9	14.6	21.8
Effective field capacity, acres per hr	5.3	7 0	8.4	10.5
Field efficiency, %	73	64	58	49
Relative effective field capacity	100	1.32	1.58	1.98

SOURCE: K. K. Barnes, Field Capacity of Row-crop Planters, *Implement & Tractor*, **76**(5):50, 1961. Reproduced with special permission from *Implement & Tractor*.

Machine efficiency is applied largely to harvesting equipment, such as combines, corn pickers, and cotton pickers and strippers. The efficiency of a machine is the percentage of the crop yield harvested by the machine. It is determined by dividing the yield per acre harvested by the machine by the total yield per acre and multiplying the result by 100. The total yield includes the amount of storm loss before the machine was operated and the amount lost by the machine plus the amount harvested by the machine.

The family farm operator who succeeds today uses knowledge of genetics, land and water use, conservation, chemistry, and physics, with business ability. He combines modern science and ancient art with

machine power. The result is greater efficiency in the production of food, clothing, and other materials for home and industry.

Custom Use of Farm Equipment. The custom use of farm equipment began, no doubt, in ancient times with whatever type of tool available by borrowing it or swapping work for its use. The old-time threshing ring was probably one of the first large-scale types of custom hiring of farm equipment in America as a business operation. Now almost all types of equipment used on the farm can be hired. Custom work is defined by Nelson and Thompson[3] as "the hiring of men with machines for performance of a specified machine task." The most common types of equipment custom hired are the harvesting machines. Aircraft for seeding and for the application of fertilizers, herbicides, and insecticides are practically always custom-hired. Aircraft and many of the harvesting machines require highly trained and skilled operators, beyond the qualifications of most farmers.

Many farmers do not have sufficient crop acreage to justify economically the investment in equipment. Some farmers, however, may be able to own and operate equipment to handle a large crop acreage up to harvest, then to reduce the effects of weather and other hazards, hire additional harvest equipment.

Many agricultural economists have studied the advantages and disadvantages of custom service of farm equipment. These are listed as follows:

ADVANTAGES AND DISADVANTAGES OF CUSTOM HIRING OF FARM EQUIPMENT

Advantages

1. Costs of ownership are eliminated.
2. Capital required to own equipment can be invested in other enterprises.
3. Some labor is furnished with hired equipment.
4. Less power and associated equipment must be obtained by the farm operator.
5. Farmers may benefit from newer machinery, techniques and skilled operation.
6. Repairs, maintenance and securing materials is the custom operator's responsibility.
7. Farm operator with smaller jobs can gain benefits of large machines.
8. Risk of premature equipment obsolescence is eliminated.

Disadvantages

1. Service may not be available when job is ready.
2. Irresponsible custom operators may do poor work and lose quantity and quality of products.
3. Greater risk of crop loss and/or quality because of time delays.
4. Risk of carrying noxious weeds and diseases from farm to farm.
5. For large jobs total cost may be higher than owning equipment.
6. Custom operators prefer large jobs, may refuse or postpone small jobs.
7. Farmers may not be able to realize return on labor released by hiring custom work done.

[3] Ted Nelson and Dale Thompson, Farm Custom Rates Paid in Nebraska in 1959, *Nebr. Ext. Ser. and U.S. Dept. Agr. Ext. Ser. E.C.* 60–806, 1959.

TABLE 26-3. THE COST OF CUSTOM WORK IN FIVE AGRICULTURAL REGIONS OF THE UNITED STATES

Rates include labor and fuel unless otherwise noted

Job	Basis of charge	North Central	North East	South	Mountain	Pacific
Harvesting						
Corn picking	Acre	$4.75	$7.00	$6.25	$7 50	$8.00
Corn, field shelling	Acre	5.50	8.75	7 50	9 50	(11.00)'
Combining:						
Oats, wheat	Acre	4.50	6 50	5 25	5.25	6.25
Soybeans	Acre	4.75	6 00	6 25		
Flax	Acre	4.00	(7.00)	4.00	(4.00)	
Grain sorghum	Acre	4.75	....	4.50	(4.25)	(6.50)
Rice	Acre	......	...	9.00		
Barley	Acre	4.50	6 25	5.00	5.25	6.00
Peanuts	Ton	. .	.	20.00		
Castor beans, hulling	Acre	(4 50)	......	(5 50)		
Cotton picking	Cwt.	....	. ..	2 75	2 25	2.00
Cotton stripping	Cwt.	. ...	...	1 50	(0 75)	
Harvesting sugar beets	Ton	(2.00)	..	...	1.90	2.00
Hay and silage making						
Filled chopping silage chopper and blower with:						
1 man, 2 wagons, 1 tractor	Hour	10 00	10.50	10 25	9.00	12.25
2 men, 2 wagons, 2 tractors	Hour	12 50	14 75	13.75	(12 25)	
2–4 men, trucks, 2 tractors	Hour	14 00	17.00	. .	(13 00)	(17.00)
Upright silo filling	Ton	1 75	2.75	2 75	(2 00)	(2 75)
Trench silo filling	Ton	1 75	.. .	2 50	2 00	(2 25)
Mowing hay	Acre	1 30	2 50	1.90	1 75	2 00
Mowing pasture	Acre	1.30	2.20	1.75	1 50	1 90
Raking hay	Acre	1 00	1 60	1 40	1 25	1 50
Crushing hay	Acre	1 50	2 50	2 00	(1 50)	(2 30)
Pickup baling:						
Twine	Bale	0 11	0 12	0.18	0.13	0 14
Wire	Bale	0 13	0 14	0 20	0.16	0 17
Round	Bale	0 10	0 10	0.17	0.11	(0 10)
Plowing and cultivating						
Plowing, moldboard:						
Spring	Acre	3 50	4.60	3 75	5 00	4 50
Fall	Acre	3.75	5 00	3 75	4 75	4 75
Sod	Acre	4.25	5.25	4.25	6 00	6.00

TABLE 26-3. THE COST OF CUSTOM WORK IN FIVE AGRICULTURAL REGIONS OF THE UNITED STATES (Continued)

Job	Basis of charge	North Central	North East	South	Moun- tain	Pacific
		Plowing and cultivating (*Continued*)				
Plowing:						
Disk	Acre	3.00	(4.50)	3.25	3.50	4.50
One-way	Acre	2.00	......	2.00	1.60	(2.50)
Disking:						
Tandem	Acre	1.50	(2.50)	2.00	1.75	2.75
Offset	Acre	1.75	(2.50)	2.50	2.25	(2.75)
Disking with harrow	Acre	1.75	2.50	2.25	2.10	3 25
Harrowing:						
Spike tooth	Acre	0.80	2.00	1.15	0.80	1.10
Spring tooth	Acre	1.25	2.25	1.60	(1.00)	1.75
Cultivating:						
Sweep cultivator	Acre	1.40	2.00	1.70	(1.30)	(2.50)
Rotary hoe	Acre	0.90	(1.90)	1.25	(0.60)	(2.20)
Weeder	Acre	1 15	1.50	1 50	(1.00)	(1.40)
Stalk cutter, power take-off	Acre	1.65	2.85	1.75	(1.85)	(2.70)
Cultipacker	Acre	1.15	1 60	1.50	(1.00)	(1.00)
Summer fallowing:						
Rod weeder	Acre	1.20	...	(2.20)	1.00	(1.00)
Graham Hoeme	Acre	1.75	.....	2 00	1 40	(2 50)
Duckfoot	Acre	2 00	....	(2 70)	1.25	(1.40)
Bordering	Acre	(2.60)	....	(2.00)	(2.25)	(2 80)
Chiseling	Acre	2 25	..	4 00	3 35	(7.25)
Plowing, deep	Acre	...	(5.75)	6.00		
Rotary tilling	Acre	3 50	...	4 00	(4 00)	(7 00)
		Planting and drilling				
Corn planting:						
Without fertilizer	Acre	1.35	2.15	1 90	2 00	2.75
With fertilizer	Acre	1.75	2.75	2.25	(2 75)	(2.90)
Drilling small grain:						
Without fertilizer	Acre	1.25	1.75	1.50	1.50	2.00
With fertilizer	Acre	1 60	2.30	2.00	(1 40)	(2.40)
Drilling soybeans	Acre	1.40	1.80	1 80		
Planting:						
Potatoes	Acre	(4.50)	(5.75)	(5.75)	(3.50)	
Cotton	Acre	......	......	1 85	(1.25)	2.75
Sugar beets	Acre	(1.75)	......	(3.50)	(2.60)	(3.00)
Broadcast seeding	Acre	0.95	1.40	1.60	(1.60)	(1.20)
Airplane:						
Seeding legumes	Acre	1.15	(1.40)	......	......	(1.20)
Seeding small grain	Acre	(1.25)	(1 50)	1.55	.....	(1 40)
Seeding rice	Acre	......	......	(1.80)	2.00	(1.75)

TABLE 26-3. THE COST OF CUSTOM WORK IN FIVE AGRICULTURAL REGIONS OF THE UNITED STATES (Continued)

Job	Basis of charge	North Central	North East	South	Moun-tain	Pacific
Spraying and dusting						
Spraying, all (avg.).	Acre	1.25	2.70	2.00	1.85	2.30
Spraying weeds W/2, 4-D.	Acre	1.60	2.75	2 25	2.10	2.25
Spraying for corn borer:						
Tractor outfit, including material.	Acre	2.35	(2.70)	2.70		
Tractor outfit, no material	Acre	1.20	(2 50)	1.40		
Aerial, no material . ..	Acre	1 50	(1.00)	1.75	(1.25)	(1.25)
Spraying:						
Potatoes..	Acre	.....	(3 30)	(3 20)	(2.75)	(2.00)
Cotton . .	Acre	. . .	. ...	(2.00)		
Dusting:						
All (avg.)	Acre	(1.10)	......	1.40	(4.00)	(0.75)
Cotton.....	Acre	(1.00)	......	1.25	(2.00)	(2.80)
Potatoes.	Acre	(1 20)	......	1.50	3.00	2.00
Airplane:						
Dusting cotton...	Acre	......	......	1 85	(1.90)	(1.75)
Spraying insecticide.. .	Acre	2.00	(2.80)	2.65	2.60	1.70
Defoliating cotton .	Acre	....	. ..	2.00	(2.60)	(1.75)
Miscellaneous						
Manure loader . .	Hour	3.50	3 75	3 20	4.00	4.20
Spreading fertilizer:						
Bulk, dry . ..	Acre	1 00	2.00	1 85	1.25	1.25
Liquid	Acre	1 10	(2.50)	1 40	1 60	(1.20)
Side dressing . ..	Acre	1.25	(2 00)	1 60	(2.00)	
Airplane . . .	Acre	1.50	(1 75)	1 50	(1.25)	(1.50)
Applying anhydrous ammonia, no materials ..	Acre	1.70	2.40	1 80	(1.50)	(1.20)
Tractors, (wheel type, no operator, no fuel):						
Large, 3-bottom or more	Hour	2.45	3.10	3.25	2 70	3.60
Medium, 2-bottom ...	Hour	1.75	2.20	2.30	2.00	2.65
Small, 1-bottom .	Hour	1.25	1.80	1.55	(1.40)	2.00
Self-propelled combine .	Hour	9.00	10.00	14 00	12.00	12.75

* Figures in parentheses not completely reliable because of few estimates.

SOURCE: 1962 Machinery Custom Rates, *Doane Agricultural Digest*. Data reproduced by special permission of the Doane Agricultural Service, Inc.

Own or Hire Farm Equipment. When a farmer needs a machine for a particular phase of his farm operation, he must, from a business standpoint, determine whether it is more economical to buy and own the machine or to hire men with machines to do the work.

Ownership essentials and cost of use of crop farm equipment have been discussed above. The prevailing custom rates for various field operations are given in Table 26-3. The farmer must determine by figuring the comparative costs if it is more profitable to own or hire the equipment.

TABLE 26-4. FORM FOR ESTIMATING MACHINERY OWNERSHIP COSTS MACHINE: 14-FOOT SELF-PROPELLED COMBINE

Item	Annual fixed costs	
	Explanation	Estimated costs
Depreciation	Original cost ($7,100) minus trade-in value at end of useful life ($710) divided by expected life of machine (10 years)	$639 00
Interest	Original cost ($7,100) plus trade-in value ($710) divided by 2 × interest rate (6%)	234 30
Taxes	Expected annual taxes to be paid on machine (estimated at 0.50% of original cost)	35.50
Insurance	Liability, fire, theft, windstorm, etc. (estimated at 0 25% of original cost)	17.75
Shelter	Portion of depreciation, interest, and maintenance of shelter used by this machine (1% of original cost)	71 00
Total annual fixed costs		$997 55

Fixed costs per unit: Total annual fixed costs ($997.55) divided by units of work done per year (800 acres) = $1.25 per acre

Ownership. Anderson and Tefertiller have developed a simple method of figuring the cost of machine ownership as shown in Table 26-4. The estimated ownership costs in the table are for a 14-foot self-propelled combine that costs $7,100 new.[4] The combine has an estimated life of 10 years or 2,000 hours and a 10 per cent trade-in value.[5]

Hire or Buy Formula. When can a farmer economically justify owning a particular machine? The following formula can be used to estimate the

[4] A part of unpublished manuscript, *Farm Machinery Decisions* by C. G. Anderson and K. R. Tefertiller, respectively, Vocational Agriculture, Farm Management Specialist and Assistant Professor, Department of Agricultural Economics and Sociology, A. & M. College of Texas, College Station, Tex.

[5] Reproduced by special permission.

approximate "break-even" point between owning a machine and hiring a custom operator.

$$\frac{\text{Total annual fixed costs}}{\text{custom rate minus operating or variable costs per unit}} = \frac{\$997.55}{\$3.00 - \$0.88\ (\$2.12)} = \text{470 acres or break-even point}$$

With the estimated cost figures used in this example, a combine owner must harvest approximately 470 acres per year economically to justify owning the machine. It should be understood that these cost figures do vary from farm to farm and are only useful as long as they are reasonably accurate and applicable to the individual situation. Cost figures should be used from local farm records.

TABLE 26-5. OPERATING OR VARIABLE COSTS PER UNIT

Item	*Cost per hour*
Fuel: 4.0 gal. per hr. @ $ 18 gal . ..	$0.72
Oil: 0.5 gal. per day @ $1.00 gal. ÷ 10-hr. day	0.05
Lubricant: $7,100 × .2% per year ÷ 200 hr. per year ..	0.07
Repair and maintenance: 40% of original cost ($2,840) ÷ 2,000 hr . . .	1 42
Operators' labor	1.25
Total operating or variable costs per hr	$3.51

Operating costs per acre: total operating costs per hour divided by acres per hour ($3.51 ÷ 4.0) = $0.88 per acre

Total costs per acre = fixed costs per acre ($1.25) plus total operating costs per acre ($0.88) = $2.13 per acre

There are other factors which the above comparison does not include. What is the value of the farmer's labor? What are timeliness and convenience worth to the farmer? Some farmers can better afford individual ownership. The final decision as to owning or hiring a machine is likely to vary among farmers.

Farm-equipment Safety. The operation of farm equipment has many hazards, and accidents can be reduced if the safety precautions shown in Fig. 26-5 are carefully followed.

Safety first is a slogan that should be kept in mind at all times. Many of the accidents that occur in operating farm equipment are the direct result of thoughtlessness and carelessness. Accidents are more likely to occur with power-operated equipment that has moving parts to perform its operating function. The tractor perhaps is involved in more farm accidents than any other type of equipment, largely because of its versatility and extensive use. The corn picker is considered a hazardous machine because of the number of accidents that happen to those who operate it. The major number of accidents result from attempts to un-

choke the downward revolving snapping rolls without disengaging the power and stopping them.

Design engineers add protective features around moving parts, but if the operator of the machine fails to use these safety features, he is likely to be involved in an accident that will cause serious injury or perhaps death.

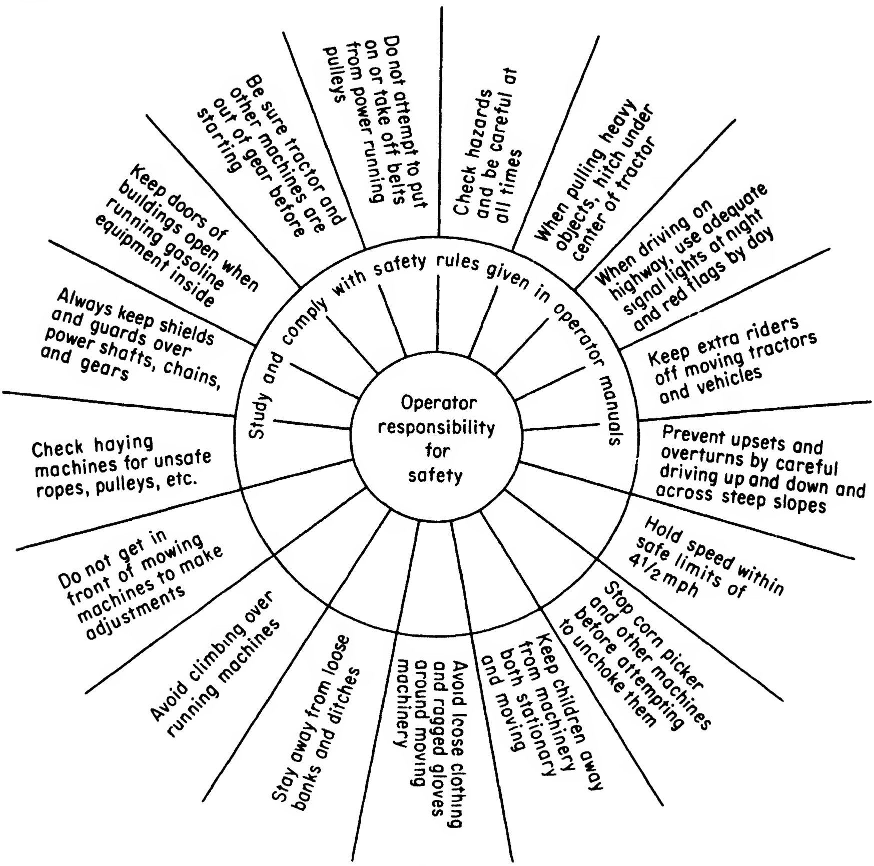

Fig. 26-5. Chart showing operator responsibility for various factors of safety in operating farm equipment. (*Drawing by author.*)

All the national societies and associations, such as the American Society of Agricultural Engineers, The Society of Automotive Engineers, The Farm Equipment Institute, The Manufacturers Association, and Dealers Association, have safety committees. The National Safety Council gives assistance to the forty-five permanently organized State Farm Safety Committees. These organizations promote safety programs, publish safe farm practice leaflets, and supply safety information to both adult

and youth rural organizations. The influence of these safety programs to prevent accidents is shown in Fig. 26-6 for five states where records have been kept for several years. The reduction in fatal farm accidents ranges from 29 per cent for Minnesota to 84 per cent for New Hampshire.

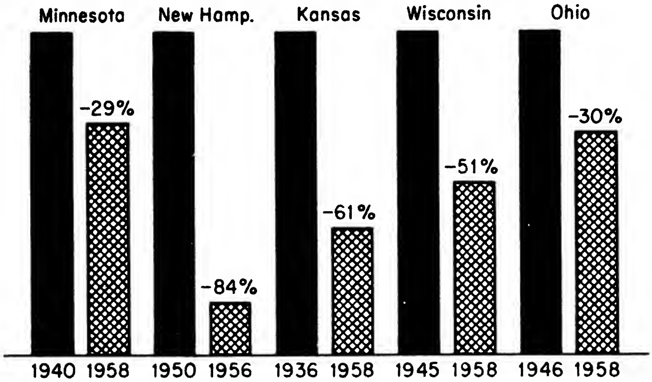

Fig. 26-6. A chart showing that fatal accidents are decreasing in states with active safety committees, safety specialists, and accident-prevention programs. (*National Safety Council.*)

Stop a minute; think and plan for safety. The operator who says, "I'm in a hurry" is likely to have an accident.

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QUESTIONS AND PROBLEMS

1. Give the 1959 U.S. Department of Agriculture definition of a farm.
2. What and when were the three great revolutions in American agriculture?
3. Discuss the importance of matching equipment to farm needs.
4. List the various fixed and variable costs involved in the ownership of farm equipment.
5. Find the annual repair cost for a two-row self-propelled cotton picker costing $15,000.
6. Define the following: (*a*) theoretical field capacity; (*b*) effective field capacity; (*c*) field efficiency; (*d*) machine efficiency.
7. Calculate the effective field capacity of a corn planter planting six rows spaced 42 inches apart and operated at a speed of 4.5 m.p.h.
8. Define farm custom work.
9. List five advantages and five disadvantages of custom hiring of farm equipment.
10. Give the formula for determining the break-even point between owning a machine and hiring custom work.
11. Give ten rules for safety in operating farm equipment.

APPENDIX

CONTENTS

TABLE 1. EQUIVALENTS

1 acre =

43,560 square feet
160 square rods
4,046.87 square meters
0.40469 hectare

1 atmosphere, standard

29.9212 inches of mercury
33.9006 feet of water
14.6969 pounds per square inch
2,116.35 pounds per square foot
1.03329 kilograms per square centimeter

1 British thermal unit

778.104 foot-pounds
0.000393 horsepower-hour
0.0003984 horsepower-hour, metric
1,054.9 joules
1,052 watt-seconds
0.000293 kilowatt-hour
107.577 kilogram-meters
0.252 calorie

1 British thermal unit per second

778.104 foot-pounds per second
1.41474 horsepower
1.43436 horsepower, metric
1,054.9 watts
1.0549 kilowatts
107.577 kilogram-meters per second
0.252 calorie per second

1 bushel

2,150.42 cubic inches
1.24446 cubic feet
32 dry quarts
8 dry gallons
35.2393 cubic decimeters

1 calorie

3,087.77 foot-pounds
3.96832 British thermal units
0.001559 horsepower-hour
0.001581 horsepower-hour, metric
4,186.17 joules
426.9 kilogram-meters
0.001163 kilowatt-hour

1 calorie per second

3,087.77 foot-pounds per second
5.61412 horsepower
5.692 horsepower, metric
3.96832 British thermal units per second
4,186.17 watts
4.18617 kilowatts
426.9 kilogram-meters per second

1 centimeter

0.3937 inch
0.0328 foot
10 millimeters

1 chain

792 inches
66 feet
0.0125 mile
20.1168 meters
0.02012 kilometer

1 decimeter, cubic

61.0234 cubic inches
0.03531 cubic foot
1.5668 liquid quarts
0.02838 bushel

1 degree centigrade

1.8 degrees Fahrenheit
0.8 degree Reaumur

1 degree Fahrenheit

0.5555 degree centigrade
0.4444 degree Reaumur

1 degree Reaumur

1.25 degrees centigrade
2.25 degrees Fahrenheit

1 foot

12 inches
0.3333 yard
0.06061 rod
0.01515 chain
0.0001894 mile
304.8 millimeters
30.48 centimeters
0.3048 meter

TABLE 1. EQUIVALENTS (Continued)

1 foot, square

144 square inches
929.03 square centimeters
0.0929 square meter

1 foot, cubic

1,728 cubic inches
29.9221 liquid quarts
7.48055 liquid gallons
0.80356 bushel

1 foot per second

0.68182 mile per hour
0.3048 meter per second
1.09728 kilometers per hour

1 foot per second per second

0.68182 mile per hour per second
0.3048 meter per second per second
1.09728 kilometers per hour per second

1 foot-pound

0.0003239 British thermal unit
0.0000005051 horsepower-hour
0.0000005121 horsepower-hour, metric
1.35573 joules
0.13826 kilogram-meter
0.0003239 calorie
0.0000003766 kilowatt-hour

1 foot-pound per second

0.001285 British thermal unit per second
0.001818 horsepower
0.001843 horsepower, metric
0.13826 kilogram-meter per second
0.0003237 calorie per second
1.35573 watts
0.001356 kilowatt

1 gallon, liquid

231 cubic inches
0.13368 cubic foot
4 liquid quarts
0.8327 British Imperial gallon
3.78543 cubic decimeters

1 gallon, dry

268.803 cubic inches
0.15556 cubic foot
4 dry quarts
0.96817 British Imperial gallon
0.125 bushel
4.40492 cubic decimeters

1 grain

0.002083 ounce, troy
0.002286 ounce, avoirdupois
0.0001736 pound, troy
0.0001429 pound, avoirdupois
0.0000648 kilogram

1 gram per centimeter

39.1983 grains per inch
0.0056 pound per inch
0.0672 pound per foot
0.10 ton, metric, per kilometer
0.10 kilogram per meter

1 gram per cubic centimeter

0.03613 pound per cubic inch
62.4283 pounds per cubic foot
1,000 kilograms per cubic meter
100 kilograms per hectoliter

1 gravity

32.1717 feet per second per second

1 hectare

107,639 square feet
2.47104 acres
0.003861 square mile
10,000 square meters
0.01 square kilometer

1 horsepower

550 foot-pounds per second
33,000 foot-pounds per minute
0.70685 British thermal unit per second
0.17812 calorie per second
76.0404 kilogram-meters per second
1.01387 horsepower, metric
745.65 watts
0.74565 kilowatt

TABLE 1. EQUIVALENTS (Continued)

1 horsepower-hour

1,980,000 foot-pounds
2,544.65 British thermal units
641.24 calories
1.01387 horsepower-hours, metric
2,684,340 joules
273,745 kilogram-meters
0.74565 kilowatt-hour

1 horsepower, metric

542.475 foot-pounds per second
0.69718 British thermal unit per second
0.98632 horsepower
0.17569 calorie per second
75 kilogram-meters per second
735.448 watts
0.73545 kilowatt

1 horsepower-hour, metric

1,952,910 foot-pounds
2,509.83 British thermal units
0.98632 horsepower-hour
2,647,610 joules
270,000 kilogram-meters
632.467 calories
0.73545 kilowatt-hour

1 inch

0.08333 foot
25.4 millimeters
0.0254 meter

1 inch of mercury

0.49119 pound per square inch
13.58 inches of water

1 inch of water

0.0361 pound per square inch
0.0735 inch of mercury

1 inch, square

0.006944 square foot
6.4516 square centimeters
0.0006453 square meter

1 inch, cubic

0.0005787 cubic foot
0.01732 liquid quart
0.0004329 liquid gallon
0.000465 bushel
16.39 cubic centimeters

1 joule

0.73761 foot-pound
0.000948 British thermal unit
0.0000003725 horsepower-hour
0.0000003777 horsepower-hour, metric
0.0002389 calorie
0.10198 kilogram-meter
0.0000002778 kilowatt-hour

1 kilogram

15,432.4 grains
32.1507 ounces, troy
35.274 ounces, avoirdupois
2.67023 pounds, troy
2.20462 pounds, avoirdupois
0.001102 ton
0.001 ton, metric
1,000 milligrams
100 centigrams
10 decigrams

1 kilogram per meter

0.056 pound per inch
0.67197 pound per foot
1.774 tons per mile
1 ton per kilometer, metric
10 grams per centimeter

1 kilogram per square centimeter

14.2234 pounds per square inch
2,048.17 pounds per square foot
1.02408 tons per square foot
0.96778 atmosphere, standard

1 kilogram per hectoliter

0.0003613 pound per cubic inch
0.62428 pound per cubic foot
0.08345 pound per liquid gallon
0.01 gram per cubic centimeter
10 kilograms per cubic meter

1 kilogram per cubic meter

0.00003613 pound per cubic inch
0.06243 pound per cubic foot

0.001 gram per cubic centimeter
0.1 kilogram per hectoliter

1 kilogram-meter

7.233 foot-pounds
0.009296 British thermal unit
0.000003653 horsepower-hour
0.000003704 horsepower-hour, metric
9.80597 joules
0.002342 calorie
0.000002724 kilowatt-hour

1 kilogram-meter per second

7.233 foot-pounds per second
0.01315 horsepower
0.01333 horsepower, metric
0.009296 British thermal unit per second
0.002342 calorie per second
9.80597 watts
0.009806 kilowatt

1 kilometer

39,370 inches
3,280.83 feet
1,000 meters

1 kilometer per hour

0.91134 foot per second
0.62137 mile per hour
0.27778 meter per second

1 kilometer per hour per second

0.91134 foot per second per second
0.623137 mile per hour per second
0.27778 meter per second per second

1 kilowatt

737.612 foot-pounds per second
1.34111 horsepower
1.35972 horsepower, metric
0.94796 British thermal unit per second
0.23888 calorie
1,000 watts
101.979 kilogram-meters per second

1 kilowatt-hour

2,655,403 foot-pounds
1.34111 horsepower-hours
1.35972 horsepower-hours, metric
3412.66 British thermal units
859.975 calories
3,600,000 joules
1,000 watt-hours
367,123 kilogram-meters

1 liter

61.023 cubic inches
1.0567 quarts
1,000 cubic centimeters

1 meter

39.37 inches
3.28083 feet
0.001 kilometer
1,000 millimeters
100 centimeters
10 decimeters

1 meter per second

3.28083 feet per second
2.23693 miles per hour
3.6 kilometers

1 meter per second per second

3.28083 feet per second per second
2.23693 miles per hour per second
3.6 kilometers per hour per second

1 meter, square

1,550 square inches
10.7639 square feet
10,000 square centimeters
100 square decimeters

1 meter, cubic

0.006102 cubic inch
0.000035 cubic foot
0.00156 liquid quart
0.000028 bushel
1,000,000 cubic centimeters
1,000 cubic decimeters

1 mile

63,360 inches
5,280 feet

TABLE 1. EQUIVALENTS (Continued)

1,760 yards
320 rods
80 chains
1,609.35 meters
1.60935 kilometers

1 mile, square

27,878,400 square feet
640 acres
2,589,999 square meters
2.59 square kilometers

1 mile per hour

1.46667 feet per second
0.44704 meter per second
1.60935 kilometers per hour

1 mile per hour per second

1.46667 feet per second
0.44704 meter per second per second
1.60935 kilometers per hour per second

1 ounce, troy

480 grains
1.09714 ounces, avoirdupois
0.08333 pound, troy
0.06857 pound, avoirdupois
0.0311 kilogram

1 ounce, avoirdupois

437.5 grains
0.91146 ounce, troy
0.07595 pound, troy
0.0625 pound, avoirdupois
0.02835 kilogram

1 pound, troy

12 ounces, troy
13.1657 ounces, avoirdupois
0.82286 pound, avoirdupois
0.0004114 ton
0.0003732 ton, metric
0.37324 kilogram

1 pound, avoirdupois

14.5833 ounces, troy
16 ounces, avoirdupois
1.21528 pounds, troy
0.0005 ton
0.0004536 ton, metric
0.45359 kilogram

1 pound per inch

12 pounds per foot
31.68 tons per mile
17.8579 tons, metric, per kilometer
178.579 grams per centimeter
17.8579 kilograms per meter

1 pound per square inch

144 pounds per square foot
0.072 ton per square foot
0.07031 kilogram per square centimeter
0.06804 atmosphere, standard

1 pound per cubic inch

1,728 pounds per cubic foot
27.6797 grams per cubic centimeter
2,767.97 kilograms per hectoliter
27,679.7 kilograms per cubic meter

1 pound per foot

0.08333 pound per inch
2.64 tons per mile
1.48816 tons, metric, per kilometer
14.8816 grams per centimeter
1.48816 kilograms per meter

1 pound per square foot

0.006944 pound per square inch
0.0004882 kilogram per square centimeter
0.0004725 atmosphere, standard

1 pound per cubic foot

0.0005787 pound per cubic inch
1.24446 pounds per bushel
0.01602 gram per cubic centimeter
1.60184 kilograms per hectoliter
16.0184 kilograms per cubic meter

1 pound per yard

0.02778 pound per inch
0.333 pound per foot
0.88 ton per mile
0.49605 ton, metric, per kilometer

TABLE 1. EQUIVALENTS (Continued)

4.96054 grams per centimeter
0.49605 kilogram per meter

1 pound per cubic yard

0.00002143 pound per cubic inch
0.03704 pound per cubic foot
0.04609 pound per bushel
0.0005933 gram per cubic centimeter
0.05933 kilogram per hectoliter
0.59327 kilogram per cubic meter

1 quart, liquid

57.75 cubic inches
0.03342 cubic foot
0.94636 cubic decimeter

1 quart, dry

67.2006 cubic inches
0.03889 cubic foot
0.25 dry gallon
0.03125 bushel
1.10123 cubic decimeters

1 radian per second

0.159155 revolution per second

1 rod

198 inches
16.5 feet
5.5 yards
0.25 chain
0.003125 mile
5.02921 meters
0.005029 kilometer

1 rod, square

39,204 square inches
272.25 square feet
0.00625 acre
0.000009766 square mile
25.293 square meters

1 ton

2,430.56 pounds, troy
2,000 pounds, avoirdupois
0.90719 ton, metric
907.185 kilograms

1 ton per mile

0.03157 pound per inch
0.37879 pound per foot
0.5637 ton, metric, per kilometer
5.63698 grams per centimeter
0.5637 kilogram per meter

1 ton, metric

2,679.23 pounds, troy
2,204.62 pounds, avoirdupois
1.10231 tons
1,000 kilograms

1 ton, metric, per kilometer

0.056 pound per inch
0.67197 pound per foot
1.774 tons per mile
10 grams per centimeter
1 kilogram per meter

1 watt

0.73761 foot-pound per second
0.001341 horsepower
0.00136 horsepower, metric
0.000948 British thermal unit per second
0.0002389 calorie per second
1 joule per second
0.001 kilowatt
0.10198 kilogram-meter per second

1 yard

36 inches
3 feet
0.9144 meter
1.0000029 yards, British

1 yard, square

1,296 square inches
9 square feet
0.83613 square meter

1 yard, cubic

46,656 cubic inches
27 cubic feet
764.559 cubic decimeters

TABLE 2. CONVERSION FACTORS

Multiply	by*	to obtain
acres	0.404687	hectares
"	4.04687×10^{-3}	square kilometers
ares	1076.39	square feet
board feet	144 sq. in. × 1 in.	cubic inches
" "	0.0833	cubic feet
centimeters	3.28083×10^{-2}	feet
"	0.3937	inches
cubic centimeters	3.53145×10^{-5}	cubic feet
" "	6.102×10^{-2}	cubic inches
cubic feet	2.8317×10^{-4}	cubic centimeters
" "	2.8317×10^{-2}	cubic meters
" "	6.22905	gallons, British Imperial
" "	28.3170	liters
" "	2.38095×10^{-2}	tons, British Shipping
" "	0.025	tons, U.S. Shipping
cubic inches	16.38716	cubic centimeters
cubic meters	35.3145	cubic feet
" "	1.30794	cubic yards
cubic yards	0.764559	cubic meters
degrees, angular	0.0174533	radians
degrees, Fahrenheit (less 32°F.)	0.5556	degrees, centigrade
" centigrade	1.8	degrees, Fahrenheit (less 32°F.)
foot pounds	0.13826	kilogram meters
feet	30.4801	centimeters
"	0.304801	meters
"	304.801	millimeters
"	1.64468×10^{-4}	miles, nautical
gallons, British Imperial	0.160538	cubic feet
" " "	1.20091	gallons, U.S.
" " "	4.54596	liters
gallons, U.S.	0.832702	gallons, British Imperial
" "	0.13368	cubic feet
" "	231.	cubic inches
" "	3.78543	liters
grams, metric	2.20462×10^{-3}	pounds, avoirdupois
hectares	2.47104	acres
"	1.076387×10^{-5}	square feet
"	3.86101×10^{-3}	square miles
horsepower, metric	0.98632	horsepower, U.S.
horsepower, U.S.	1.01387	horsepower, metric
inches	2.54001	centimeters
"	2.54001×10^{-2}	meters
"	25.4001	millimeters
kilograms	2.20462	pounds
"	9.84206×10^{-4}	long tons
"	1.10231×10^{-3}	short tons
kilogram meters	7.233	foot pounds
kilograms per meter	0.671972	pounds per foot
kilograms per square centimeter	14.2234	pounds per square inch
kilograms per square meter	0.204817	pounds per square foot
" " " "	9.14362×10^{-5}	long tons per square foot
kilograms per square millimeter	1422.34	pounds per square inch
" " " "	0.634973	long tons per square inch
kilograms per cubic meter	6.24283×10^{-2}	pounds per cubic foot
kilometers	0.62137	miles, statute
"	0.53959	miles, nautical
liters	0.219975	gallons, British Imperial

TABLE 2. CONVERSION FACTORS (Continued)

Multiply	by*	to obtain
liters	0.26417	gallons, U.S.
"	3.53145×10^{-2}	cubic feet
meters	3.28083	feet
"	39.37	inches
"	1.09361	yards
miles, statute	1.60935	kilometers
" "	0.8684	miles, nautical
miles, nautical	6080.204	feet
" "	1.85325	kilometers
" "	1.1516	miles, statute
millimeters	3.28083×10^{-3}	feet
"	3.937×10^{-2}	inches
pounds, avoirdupois	453 592	grams, metric
" "	0.453592	kilograms
" "	4.464×10^{-4}	tons, long
" "	4.53592×10^{-4}	tons, metric
pounds per foot	1.48816	kilograms per meter
pounds per square foot	4.88241	kilograms per square meter
pounds per square inch	7.031×10^{-2}	kilograms per square centimeter
" " " "	7.031×10^{-4}	kilograms per square millimeter
pounds per cubic foot	16.0184	kilograms per cubic meter
radians	57.29578	degrees, angular
square centimeters	0.1550	square inches
square feet	9.29034×10^{-4}	ares
" "	9.29034×10^{-6}	hectares
" "	0.0929034	square meters
square inches	6.45163	square centimeters
" "	645.163	square millimeters
square kilometers	247.104	acres
" "	0.3861	square miles
square meters	10.7639	square feet
" "	1.19599	square yards
square miles	259.0	hectares
" "	2.590	square kilometers
square millimeters	1.550×10^{-3}	square inches
square yards	0.83613	square meters
tons, long	1016.05	kilograms
" "	2240.	pounds
" "	1.01605	tons, metric
" "	1.120	tons, short
tons, long, per square foot	1.09366×10^{4}	kilograms per square meter
tons, long, per square inch	1.57494	kilograms per square millimeter
tons, metric	2204.62	pounds
" "	0.98421	tons, long
" "	1.10231	tons, short
tons, short	907.185	kilograms
" "	0.892857	tons, long
" "	0.907185	tons, metric
tons, British Shipping	42.00	cubic feet
" " "	1.050	tons, U.S. Shipping
tons, U.S. Shipping	40.0	cubic feet
" " "	0.952381	tons, British Shipping
yards	0.914402	meters

* The expressions $\times 10^{-2}$, $\times 10^{-3}$, $\times 10^{-4}$, $\times 10^{-5}$, and $\times 10^{-6}$, following certain multipliers, indicate that the decimal point in the product—of left-column value times multiplier—is to be moved respectively 2, 3, 4, 5, or 6 places to the left.

TABLE 3. CONVERSION OF MILLIMETERS TO INCHES

Mm.		*In.*	*Mm.*		*In.*	*Mm.*		*In.*	*Mm.*		*In.*
1	=	0.03937	26	=	1 02362	51	=	2.00787	76	=	2.99212
2	=	0.07874	27	=	1.06299	52	=	2.04724	77	=	3.03149
3	=	0.11811	28	=	1.10236	53	=	2.08661	78	=	3.07086
4	=	0.15748	29	=	1.14173	54	=	2.12598	79	=	3.11023
5	=	0.19685	30	=	1.18110	55	=	2.16535	80	=	3.14960
6	=	0.23622	31	=	1.22047	56	=	2.20472	81	=	3.18897
7	=	0.27559	32	=	1.25984	57	=	2.24409	82	=	3.22834
8	=	0.31496	33	=	1.29921	58	=	2.28346	83	=	3.26771
9	=	0.35433	34	=	1.33858	59	=	2.32283	84	=	3.30708
10	=	0.39370	35	=	1.37795	60	=	2.36220	85	=	3.34645
11	=	0.43307	36	=	1.41732	61	=	2.40157	86	=	3.38582
12	=	0.47244	37	=	1.45669	62	=	2.44094	87	=	3 42519
13	=	0.51181	38	=	1.49606	63	=	2 48031	88	=	3.46456
14	=	0.55118	39	=	1.53543	64	=	2 51968	89	=	3.50393
15	=	0.59055	40	=	1.57480	65	=	2.55905	90	=	3.54330
16	=	0.62992	41	=	1.61417	66	=	2.59842	91	=	3.58267
17	=	0.66929	42	=	1.65354	67	=	2.63779	92	=	3.62204
18	=	0.70866	43	=	1.69291	68	=	2.67716	93	=	3.66141
19	=	0 74803	44	=	1.73228	69	=	2.71653	94	=	3.70078
20	=	0 78740	45	=	1.77165	70	=	2 75590	95	=	3.74015
21	=	0.82677	46	=	1.81102	71	=	2.79527	96	=	3.77952
22	=	0 86614	47	=	1.85039	72	=	2.83464	97	=	3.81889
23	=	0.90551	48	=	1.88976	73	=	2 87401	98	=	3.85826
24	=	0 94488	49	=	1 92913	74	=	2 91338	99	=	3.89763
25	=	0 98425	50	=	1.96850	75	=	2 95275	100	=	3.93700

TABLE 4. FRACTIONS OF AN INCH AND DECIMAL EQUIVALENTS

			1/64	0.015625
		1/32	....	0.03125
			3/64	0.046875
		1/16	....	0.0625
			5/64	0.078125
		3/32	....	0.09375
			7/64	0.109375
1/8	....	....	....	0.125
			9/64	0.140625
		5/32	....	0.15625
			11/64	0.171875
	3/16	....	....	0.1875
			13/64	0.203125
		7/32	....	0.21875
			15/64	0.234375
1/4	....	....	....	0.250
			17/64	0.265625
		9/32	....	0.28125
			19/64	0.296875
	5/16	....	....	0.3125
			21/64	0.328125
		11/32	....	0.34375
			23/64	0.359375
3/8	....	....	....	0.375
			25/64	0.390625
		13/32	....	0.40625
	7/16	....	....	0.4375
		15/32	....	0.46875
1/2	....	....	....	0.500
		17/32	....	0.53125
	9/16	....	....	0.5625
		19/32	....	0.59375
5/8	....	....	....	0.625
		21/32	....	0.65625
	11/16	....	....	0.6875
		23/32	....	0.71875
3/4	....	....	....	0.750
		25/32	....	0.78125
	13/16	....	....	0.8125
		27/32	....	0.84375
7/8	....	....	....	0.875
		29/32	....	0.90625
	15/16	....	....	0.9375
		31/32	....	0.96875
1	....	....	....	1.0000

TABLE 5. CONVERTING INCHES AND FRACTIONS OF AN INCH INTO DECIMALS OF A FOOT

		1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″	
		.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167	
1/16	.0052	.0885	.1719	.2552	.3385	.4219	5052	.5885	.6719	.7552	.8385	.9219	1/16
1/8	.0104	.0938	.1771	.2604	3438	.4271	.5104	.5938	6771	.7604	.8438	.9271	1/8
3/16	.0156	.0990	.1823	.2656	3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323	3/16
1/4	.0208	.1042	.1875	.2708	3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375	1/4
5/16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427	5/16
3/8	.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	9479	3/8
7/16	.0365	.1198	.2031	.2865	.3698	4531	.5365	.6198	.7031	.7865	.8698	.9531	7/16
1/2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	7083	.7917	8750	.9583	1/2
9/16	.0469	.1302	.2135	.2969	3802	.4635	.5469	.6302	7135	.7969	.8802	.9635	9/16
5/8	.0521	.1354	.2188	.3021	3854	.4688	5521	.6354	.7188	8021	8854	.9688	5/8
11/16	.0573	.1406	.2240	.3073	.3906	4740	.5573	.6406	.7240	.8073	.8906	.9740	11/16
3/4	.0625	.1458	.2294	.3125	3958	.4792	5625	.6458	.7292	.8125	8958	9792	3/4
13/16	.0677	.1510	.2344	.3177	.4010	4844	.5677	.6510	.7344	8177	9010	.9844	13/16
7/8	.0729	.1563	.2396	.3229	.4063	.4896	.5729	6563	.7396	.8229	.9063	.9896	7/8
15/16	.0781	.1615	.2448	3281	4115	4948	5781	.6615	.7448	.8281	.9115	9948	15/16

TABLE 6. DRAFT AND POWER REQUIREMENTS OF CROP MACHINES

Machine	*Normal Range*
Tillage:	
Plow	5–12 p.s.i. of furrow section
Lister	400–750 lb. per row
One-way disk	150–350 lb. per ft. width
Single-disk harrow	40–130 lb. per ft. width
Tandem-disk harrow	80–160 lb. per ft. width
Tandem-disk harrow, 22-in. diameter, 9-in. spacing	170–225 lb. per ft. width, or 90% of weight
Spike-tooth harrow	30–60 lb. per ft. width
Spring-tooth harrow	75–150 lb. per ft. width
Duck-foot field cultivator	90–160 lb. per ft. width
Roller	30–60 lb. per ft. width
Subsoiler	80–160 lb. per in. of depth*
Planting:	
Grain drill	30–80 lb. per ft. width
Corn planter	80–120 lb. per row
Cultivating:	
Rotary hoe	30–60 lb. per ft. width
Corn cultivator	22–95 lb. per shovel
Spring-tooth weeder	25–35 lb. per ft. width
Rod weeder	80–110 lb. per ft. width
Harvesting:	
Mower	60–100 lb. per ft. width
Grain binder	65–150 lb. per ft. width
Thresher	0.8–1.2 hp. per in. cylinder width
Combine, 5 and 6 ft	2–4½ (pto) hp. per ft. of cutter bar
Combine, 8–12 ft	Engine with 2–3 net hp. per ft. of cutter bar
Corn picker, 2-row	2–5 (pto) hp. per row
Stationary silage cutter	0.761–1.60 hp.-hr. per ton
Husker-shredder	0.25–0.35 hp.-hr. per bu.
Pickup baler	Engine with 15–25 net hp.
Forage harvester	1–3 (pto) hp.-hr. per ton of grass silage at ½-in. cut

* In certain Southern and Far Western soils, draft figures ranging up to a maximum of approximately double the above have been recorded.

SOURCE: *Agr. Engin. Yearbook*, 1962.

TABLE 7. HISTORICAL DATES IN THE DEVELOPMENT OF FARM EQUIPMENT IN THE UNITED STATES

Soil preparation

1788	Thomas Jefferson applied mathematics to the plow moldboard
1797	Cast-iron moldboard plow patented
1814	Iron plow with replaceable parts patented
1837	Steel plow industry began
1847	Revolving plow moldboard patented (disk plow)
1860s	Chisel cultivators came into use
1864	Successful sulky (riding) plow
1867	Walking gang plow supported on wheels
1868	Soft-center steel for plows
1869	Chilled plow process patented
1869	Spring-tooth harrow patented
1877	Disk harrow with concave blades patented
1880	Lister produced commercially
1884	First three-wheel riding plow
1895	Heavy-duty, deep-tillage chisel to penetrate subsoil of irrigated land
1898	High-lift, frame-type gang sulky plows
1900	Heavy-duty, deep-tillage implements in commercial production
1910	Rod weeder for fallow land farming
1915	Unit frame tractor plows introduced
1923	Combination tool carrier for heavy-duty implements
1924	Offset disk harrow
1927	One-way or wheatland disk plows first sold in large numbers
1935–1940	Lift-type mounted plow introduced
1941	Hydraulic remote control of drawn implements
1949	Wheel disk harrow introduced
1953	Safety trip plow beams in use

Planting and cultivating

1799	Seeding machine patented
1839	Two-row corn planter patented
1840–1841	Grain drill feeding mechanism patents
1846	First wheel cultivator (one-horse)
1851	Force-feed grain drill
1857	Early-type broadcast seeder
1860	Two-row corn planter with hand control drop for cross-checking
1863	Commercially successful riding cultivator
1870s	Straddle-row, two-horse cultivators (one row)
1875	Automatic check rowers for planting corn
1880	Potato planters in use
1890	Transplanting machine for tobacco and vegetable plants
1890s	Accumulative or hill-drop corn planter
1912	Rotary hoe produced commercially
1917	Two-row potato planters
1921	Tool bar idea for mounting tillage tools on tractors
1924	Mounted-type tractor implements

TABLE 7. HISTORICAL DATES IN THE DEVELOPMENT OF FARM EQUIPMENT IN THE UNITED STATES (Continued)

Planting and cultivating (*Continued*)

1929	Attachments for placing fertilizer in bands
1939	Single-seed beet planters made available commercially
1942	First commercial plantings of segmented beet seed
1950	Sodland seeder introduced
1957	Planter attachments to apply liquid fertilizers

Harvesting

1831	Accepted birth date of the type of reaper that attained success
1836	Combine built in Michigan
1837	Thresher patented which introduced principles of later machines
1843	Vibrating principle in threshers patented
1846–1847	Reaper got into quantity production
1848–1849	Push-type headers invented
1854	Self-rake reaper produced in quantity
1858	First successful harvester on which men could ride to bind
1863	Wire binder for harvester produced in large numbers
1871	Horse-drawn potato digger
1872	Wire binder adapted to Marsh-type harvester
1878	Successful twine binder for Marsh-type harvester
1880	Factory production of combines started on Pacific Coast
1880	First important corn picker patent
1885	Corn husker-shredder appeared
1886	Potato diggers built commercially
1892	Corn binder patented (self-binding)
1904	First steel thresher
1909	Corn picker built commercially
1926	Cotton strippers built commercially for the High Plains
1928	Two-row PTO-operated corn picker and one-row mounted picker
1929	Two-row mounted corn picker
1935	One-man power take-off combine
1938	Self-propelled combine in America
1940–1945	Potato harvester
1941	Successful cotton picker built
1943	First appreciable use of commercial sugar beet harvesters
1943	Tractor-mounted cotton strippers
1946	Self-propelled corn picker
1949	Portable batch dryer available
1950	Self-propelled windrower
1954	Corn head attachment for combine available commercially
1958	Shelling attachment for corn pickers

Hay and forage

1820	Horse-drawn revolving hay rake
1822	Mower or grass-cutting machine patented
1850	Hand dump rake with iron or steel teeth
1853	Early-type hay press
1853–1860	Two-wheeled mowers with flexible or hinged bars
1855–1870	Seven patents on iron or steel tedders with seat for driver

TABLE 7. HISTORICAL DATES IN THE DEVELOPMENT OF FARM EQUIPMENT IN THE UNITED STATES (Continued)

Hay and forage (*Continued*)

1864	Harpoon-type hay fork patented	1932	Field pickup baler introduced
1867	Hay carrier patented	1936	Forage harvester built commercially
1872	Continuous hay press invented	1940	Automatic, self-tying pickup baler
1874	Successful mechanical hay loader	1940	Power take-off driven side delivery rake
1876	Ensilage cutters appeared	1945	Mow hay finishers built commercially
1882	Portable hay stacker	1945	Hay crusher built commercially
1885	Sweep rakes in use	1946	Silo unloader introduced
1890	Hay loader reaches commercial importance	1952	Flail-type forage harvester
1893	Early-type side delivery rake	1953	Dynamically balanced mower introduced
1914	Reel-type side delivery rake	1958	Self-propelled baler

Specialized equipment

1840	Wooden hand pump—first use of suction to lift water	1895	First milking machine with intermittent suction
1842	First grain elevator constructed	1897	Litter carrier and feed carrier introduced
1844	First American incubator invented	1900	First power sprayer operated by gasoline engine
1850	Feed cutters—self-feeding, knife cutting against steel	1900	Riding, single-row stalk cutter
1854	Self-regulating windmill	1902	First commercially successful cylinder corn shellers
1855	Portable grinding mills with metallic plates	1902	Steel stanchions for dairy cows
1850s	Picker-wheel-type sheller, hand and power	1902	Portable grain elevators
1850s	Specialized garden implements	1904–1905	Steel stalls and alignment device to make stanchions adjustable
1860	Self-feeding device for corn shellers	1910	Electric water systems produced in quantity
1865	First manure spreader, wagon type	1910	Colony-type heated brooder for baby chicks
1877	First commercially known spreader—endless apron	1911	Pressure regulator and air chamber for power sprayers
1878	First milking machine using vacuum principle	1912	Automatic, individually operated water bowls for cows
1879	Centrifugal cream separator introduced	1914	Land leveler for irrigation farming
1883	Steel windmill and tower	1914–1917	Power-operated milking machines introduced
1885	First American factory-made incubator	1916	Garden tractors introduced
1887	First traction sprayer		
1890	Gasoline engines for sta-		

TABLE 7. HISTORICAL DATES IN THE DEVELOPMENT OF FARM EQUIPMENT IN THE UNITED STATES (Continued)

Specialized equipment (*Continued*)

1924	Electric ventilating system for dairy barns	1944	Dusters with attachments to inject liquid
1925	Two-row, tractor-drawn rolling stalk cutter	1944	Low-pressure, low-volume sprayers
1925	Air-blast-type sprayer introduced	1947	Equipment to apply fertilizer in vapor form (anhydrous ammonia)
1926	Jet-type pumps introduced		
1930	Portable sprinkler irrigation	1948	Submersible pump (water well)
1937	Automatic barn cleaner built commercially	1948	Self-propelled sprayer
1938	Tractor loader built commercially	1948–1950	Pipeline milking important commercially
1941	Precision planting of vegetable seed	1950s	Automatic feeding of beef and poultry

Tractor power

1850	Portable steam engines for farm use	1930	Farm tractor equipped with power lift
1876	Steam traction engine	1931	First diesel-powered track-type tractor
1892–1901	Experimental models, gas traction engines	1932	Low-pressure rubber tires introduced for farm tractors
1903	Gas traction engines produced commercially	1935	Factory-built, high-compression tractors to burn leaded gasoline
1904	Track-type traction engine		
1906–1907	The word "tractor" came into use	1935	Hydraulic lift equipment on the tractor
1908	First gasoline track-type tractor	1939	Weight transfer for increased traction
1913	Frameless or unit design in farm tractors	1941	First factory-built LP gas tractors
1915	"Motor cultivator" type tractor	1944	Power take-off and drawbar dimensions standardized
1919	Farm tractor equipped with power take-off	1946	Transmission clutch for live power take-off
1920	Starter and lights for tractors	1949	Hydraulic remote-control cylinder dimensions standardized
1924	Cultivating or tricycle-type tractor	1954–1958	"On-the-go" and automatic shifting of tractor transmissions
1924	Mounted-type tractor implements introduced		

SOURCE: *Land of Plenty*, Farm Equipment Institute, 1959.

TABLE 8. MILES PER HOUR FOR GIVEN TIRE SIZE

R.p.m.	12×38	11×38	10×38	9×38	9×36	9×32	11×28	10×28	10×24	9×24
12	2.1	2.0	1.9	1 9	1.8	1.6	1 6	1.6	1.4	1.4
13	2.2	2 1	2 1	2 0	2.0	1 8	1.8	1 7	1.5	1.5
14	2.4	2.3	2.2	2 2	2 1	1 9	1.9	1.8	1.7	1.6
15	2.6	2.5	2.4	2 3	2 2	2.1	2.0	2.0	1.8	1.7
16	2.7	2 6	2 6	2.5	2.4	2.2	2 2	2.1	1.9	1.8
17	2.9	2.8	2.7	2.6	2.5	2.3	2.3	2.2	2.0	2.0
18	3.1	3.0	2.9	2 8	2 7	2.5	2.4	2.4	2.1	2.1
19	3.2	3.1	3 0	2.9	2.8	2.6	2.6	2.5	2.2	2.2
20	3.4	3 3	3 2	3.1	3.0	2.7	2.7	2.6	2.4	2.3
21	3.6	3.5	3 4	3.3	3 1	2 9	2.8	2.8	2.5	2.4
22	3.8	3.6	3 5	3.4	3 3	3 0	3.0	2.9	2.6	2.5
23	3.9	3.8	3.7	3 5	3 4	3.1	3 1	3 0	2.7	2.6
24	4.1	4.0	3 8	3 6	3.6	3.3	3 3	3 1	2 8	2.8
25	4.3	4.1	4 0	3 8	3 7	3.4	3.4	3 3	3 0	2.9
26	4 4	4.3	4 2	3 9	3 9	3 6	3.5	3 4	3 1	3.0
27	4 6	4.5	4 3	4 1	4 0	3 7	3.7	3 5	3 2	3.1
28	4.8	4.6	4 5	4 2	4 2	3.8	3.8	3.7	3.3	3.2
29	4.9	4.8	4 6	4 5	4 3	4 0	3 9	3.8	3.4	3.3
30	5.1	5 0	4 8	4 6	4 5	4 1	4.1	3 9	3 5	3.4
31	5.3	5.1	5 0	4 8	4 6	4 2	4.2	4 1	3.7	3.6
32	5 5	5.3	5 1	5 0	4 8	4 4	4 3	4.2	3 8	3.7
33	5.6	5 5	5 3	5 1	4.9	4 5	4 5	4 3	3.9	3.8
34	5.8	5.6	5 4	5 3	5.1	4.6	4 6	4 4	4.0	3.9
35	6.0	5.8	5 6	5 4	5 2	4.8	4 7	4 6	4.1	4.0
36	6.1	5.9	5 8	5 6	5 4	4 9	4.9	4 7	4.3	4.1
37	6.3	6.1	5 9	5 7	5.5	5 1	5.0	4.8	4.4	4.2
38	6.5	6.3	6 1	5 9	5 7	5.2	5.1	5.0	4 5	4.4
39	6.7	6.4	6.2	6 0	5 8	5.3	5.3	5 1	4.6	4.5
40	6.8	6.6	6 4	6 2	6 0	5.5	5.4	5 2	4.7	4.6
41	7.0	6 8	6 6	6 3	6 1	5.6	5 5	5 4	4.9	4.7
42	7.2	7.0	6 7	6 5	6.3	5.8	5 7	5.5	5.0	4.8
43	7.3	7 1	6 9	6 7	6.4	5.9	5 8	5.6	5.1	4.9
44	7.5	7.3	7 1	6.8	6 6	6 0	6 0	5.8	5 2	5.1
45	7.7	7.4	7 2	7 0	6 7	6 2	6 1	5 9	5 3	5.2
46	7.8	7 6	7 4	7 1	6.9	6 3	6 2	6.0	5 4	5.3
47	8.0	7 8	7 5	7 3	7 0	6 4	6 4	6 1	5 6	5.4
48	8.2	7 9	7 7	7 4	7 2	6 6	6 5	6 3	5 7	5.5
49	8.4	8.1	7 8	7 6	7 3	6 7	6 6	6 4	5 8	5.6
50	8.5	8.3	8 0	7 7	7 5	6.8	6 8	6.5	5 9	5.7
51	8.7	8.4	8.2	7 9	7.6	7.0	6.9	6.7	6 0	5.9
52	8.9	8.6	8 3	8 1	7 8	7 1	7 0	6.8	6.2	6.0
53	9.0	8.8	8 5	8.2	7.9	7.3	7 2	6.9	6.3	6.1
54	9.2	8.9	8 6	8 4	8 1	7.4	7 3	7.1	6.4	6.2
55	9.4	9.1	8 8	8 5	8 2	7.5	7 4	7.2	6.5	6.3
56	9.5	9 2	9 0	8 7	8.3	7 7	7.6	7 3	6.6	6.4

TABLE 9. TRACTOR SPEED IN MILES PER HOUR AND FEET PER MINUTE

M.p.h.	Ft. per min.	M.p.h.	Ft. per min.
2.0	176	4.1	361
2.1	185	4.2	370
2.2	194	4.3	379
2.3	202	4.4	387
2.4	211	4.5	396
2.5	220	4.6	405
2.6	229	4.7	414
2.7	237	4.8	422
2.8	246	4.9	431
2.9	255	5.0	440
3.0	264	5.1	449
3.1	273	5.2	458
3.2	282	5.3	468
3.3	292	5.4	476
3.4	299	5.5	484
3.5	308	5.6	493
3.6	317	5.7	502
3.7	325	5.8	510
3 8	334	5.9	519
3.9	343	6.0	528
4.0	352		

TABLE 10. MILES TRAVELED IN TILLING AN ACRE OF LAND WITH VARIOUS WIDTHS OF CUT

Width of cut, in.	*Miles traveled*
10	9.9
11	9.0
12	8.2
13	7.6
14	7.0
15	6.6
16	6.2
24	4.1
28	3.5
32	3.1
36	2.8
40	2.5
42	2.4
48	2.1
56	1.8
64	1.6
72	1.4
80	1 24
84	1.18
96	1 03
108	0 92
120	0.82
132	0.75
144	0 69

TABLE 11. MILES TRAVELED IN PLANTING OR CULTIVATING AN ACRE FOR 40-INCH (3.33-FOOT) ROW SPACING

Number of rows	*Miles traveled*
1	2.48
2	1.24
4	0.62
6	0.41
8	0 31

TABLE 12. ACRES PLANTED OR CULTIVATED IN TRAVELING ONE MILE FOR 40-INCH (3.33-FOOT) ROW SPACING

Number of rows	*Acres per mile*
1	0.40
2	0.81
4	1.62
6	2.42
8	3.23

TABLE 13. PLANTS PER ACRE FOR 40-INCH ROW SPACING

Distance apart in row, in.	Plants per foot	Plants per acre
12	1	13,081
6	2	26,162
4	3	39,243
3	4	52,324
2.4	5	65,405
2.0	6	78,486
1.7	7	91,567
1.5	8	104,480
1.3	9	117,772
1.2	10	130,081
1 09	11	143,891
1.00	12	156,972

TABLE 14. MULTIPLYING FACTOR FOR CONVERTING POUNDS PER ROW TO POUNDS PER ACRE

Row spacing, in.	Row length, ft.																	Linear ft. per acre
	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	300	400	
10	5,227.2	2,613.6	1,742.4	1,306.8	1,045.4	871.2	746.7	653.4	580.8	522.7	435.6	373.4	326.7	290.4	261.4	174.2	130.7	52,272
11	4,752.0	2,376.0	1,584.0	1,188.0	950.4	792.0	678.9	594.0	528.0	475.2	396.0	339.4	297.0	264.0	237.6	158.4	118.8	47,520
12	4,356.0	2,178.0	1,452.0	1,089.0	871.2	726.0	622.3	544.5	484.0	435.6	363.0	311.1	272.3	242.0	217.8	145.2	108.9	43,560
13	4,020.9	2,010.5	1,340.3	1,005.2	804.2	670.2	574.4	502.6	446.8	402.1	335.1	287.2	251.3	223.4	201.1	134.0	100.5	40,209
14	3,733.7	1,866.9	1,244.6	933.4	746.7	622.3	533.4	466.7	414.9	373.4	311.1	266.7	233.4	207.4	186.7	124.5	93.3	37,337
15	3,484.8	1,742.4	1,161.6	871.2	697.0	580.8	497.8	435.6	387.2	348.5	290.4	248.9	217.8	193.6	174.2	116.2	87.1	34,848
16	3,267.0	1,633.5	1,089.0	816.8	653.4	544.5	466.7	408.4	363.0	326.7	272.3	233.4	204.2	181.5	163.4	108.9	81.7	32,670
17	3,074.8	1,537.4	1,024.9	768.7	615.0	512.5	439.3	384.4	341.6	307.5	256.2	219.6	192.2	170.8	153.7	102.5	76.9	30,748
18	2,904.0	1,452.0	968.0	726.0	580.8	484.0	414.9	363.0	322.7	290.4	242.0	207.4	181.5	161.3	145.2	96.8	72.6	29,040
19	2,751.2	1,375.6	917.1	687.8	550.2	458.5	393.0	343.9	305.7	275.1	229.3	196.5	172.0	152.8	137.6	91.7	68.8	27,512
20	2,613.6	1,306.8	871.2	653.4	522.7	435.6	373.4	326.7	290.4	261.4	217.8	186.7	163.4	145.2	130.7	87.1	65.3	26,136
21	2,489.1	1,244.6	829.7	622.3	497.8	414.9	355.6	311.1	276.6	248.9	207.4	177.8	155.6	138.3	124.5	83.0	62.2	24,891
22	2,376.0	1,188.0	792.0	594.0	475.2	396.0	339.4	297.0	264.0	237.6	198.0	169.7	148.5	132.0	118.8	79.2	59.4	23,760
23	2,272.7	1,136.4	757.6	568.2	454.4	378.8	324.7	284.1	252.5	227.3	189.4	162.3	142.0	126.3	113.6	75.8	56.8	22,727
24	2,178.0	1,089.0	726.0	544.5	435.6	363.0	311.1	272.3	242.0	217.8	181.5	155.6	136.1	121.0	108.9	72.6	54.5	21,780
25	2,090.9	1,045.5	697.0	522.7	418.2	348.5	298.7	261.4	232.3	209.1	174.2	149.4	130.7	116.2	104.6	69.7	52.3	20,909
26	2,010.5	1,005.3	670.2	502.6	402.1	335.1	287.2	251.3	223.4	201.1	167.5	143.6	125.7	111.7	100.5	67.0	50.3	20,105
27	1,936.0	968.0	645.3	484.0	387.2	322.7	276.6	242.0	215.1	193.6	161.3	138.3	121.0	107.6	96.8	64.5	48.4	19,360
28	1,866.9	933.5	622.3	466.7	373.4	311.2	266.7	233.4	207.4	186.7	155.6	133.4	116.7	103.7	93.4	62.2	46.7	18,669
29	1,802.5	901.3	600.8	450.6	360.5	300.4	357.5	225.3	200.3	180.3	150.2	128.8	112.7	100.1	90.1	60.1	45.1	18,025
30	1,742.4	871.2	580.8	435.6	348.5	290.4	248.9	217.8	193.6	174.2	145.2	124.5	108.9	96.8	87.1	58.1	43.6	17,424
31	1,686.2	843.1	562.1	421.6	337.2	281.0	240.9	210.8	187.4	168.6	140.5	120.4	105.4	93.7	84.3	56.2	42.2	16,862
32	1,633.5	816.8	544.5	408.4	326.7	272.3	233.4	204.2	181.5	163.4	136.1	116.7	102.1	90.8	81.7	54.5	40.8	16,335
33	1,584.0	792.0	528.0	396.0	316.8	264.0	226.3	198.0	176.0	158.4	132.0	113.1	99.0	88.0	79.2	52.8	39.6	15,840
34	1,537.4	768.7	512.5	384.4	307.5	256.2	219.6	192.2	170.8	153.7	128.1	109.8	96.1	85.4	76.9	51.3	38.4	15,374

TABLE 14. MULTIPLYING FACTOR FOR CONVERTING POUNDS PER ROW TO POUNDS PER ACRE (Continued)

Row spacing, in.	Row length, ft.																	Linear ft. per acre
	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	300	400	
35	1,493.5	746 8	497.8	374 4	298.7	248 9	213.4	186 7	165 9	149 4	124.5	106.7	93.3	83.0	74.7	49.8	37.4	14,935
36	1,452.0	726.0	484.0	363.0	290.4	242 0	207.4	181 5	161.3	145.2	121 0	103.7	90 8	80.7	72.6	48.4	36.3	14,520
37	1,412.8	706.4	470.9	353 2	282 6	235.5	201.8	176.6	157.0	141.3	117 7	100.9	88.3	78.5	70.6	47.1	35.3	14,128
38	1,375.6	687.8	458.5	343.9	275 1	229.3	196.5	172.0	152.8	137.6	114.6	98.3	86.0	76.4	68.8	45.9	34.4	13,756
39	1,340.3	670.2	446.8	335.1	268 1	223.4	191.5	167 5	148.9	134.0	111.7	95.7	83.8	74.5	67.0	44.7	33.5	13,403
40	1,306.8	653.4	435.6	326.7	261.4	217.8	186.7	163 4	145.2	130.7	108 9	93.3	81.7	72.6	65.3	43.6	32.7	13,068
41	1,274.9	637.5	425.0	318 7	255.0	212.5	182.1	159.4	141 7	127.5	106 2	91.1	79.7	70.8	63.8	42.5	31.9	12,749
42	1,244.6	622.3	414.9	311.2	248.9	207.4	177.8	155 6	138.3	124.5	103.7	88.9	77.8	69.1	62.2	41.5	31.1	12,446
45	1,161.6	580.8	387 2	290.4	232 3	193 6	165.9	145.2	129.1	116.2	96.8	83.0	72.6	64.5	58.1	38.7	29.0	11,616
48	1,089.0	544.5	363.0	272.3	217.8	181 5	155 6	136.1	121.0	108.9	90.8	77.8	68.1	60.5	54.5	36.3	27.2	10,890
54	968.0	484.0	322 7	242.0	193.6	161 3	138.3	121 0	107.6	96.8	80.7	69.1	60.5	53.8	48.4	32.3	24.2	9,680
60	871 2	435.6	290.4	217.8	174 2	145.2	124.5	108.9	96.8	87.1	72 6	62.2	54.5	48.4	43.6	29.0	21.8	8,712
66	792.0	396 0	264.0	198 0	158.4	132.0	113.1	99 0	88.0	79.2	66.0	56.6	49.5	44.0	39.6	26.4	19.8	7,920
72	726.0	363.0	242.0	181.5	145 2	121.0	103.7	90.8	80.7	72.6	60 5	51.9	45.4	40.3	36.3	24.2	18.2	7,260

SOURCE: U.S. Dept. Agr., Agricultural Engineering Branch.

TABLE 15. TEMPERATURE CONVERSION TABLE

The numbers in italics in the center column refer to the temperature C in either centigrade or Fahrenheit) which one desires to convert to the other scale. If converting Fahrenheit to centigrade, the equivalent temperature will be found in the left column. If converting centigrade to Fahrenheit, the equivalent temperature will be found in the column on the right.

−100 to 23			24 to 57			58 to 91			92 to 330			340 to 670			680 to 1000		
C	C. or F.	F	C	C. or F.	F	C	C. or F.	F	C	C. or F.	F	C	C. or F.	F	C	C. or F.	F
−73	*−100*	−148	−4.4	*24*	75.2	14.4	*58*	136.4	33.3	*92*	197.6	171	*340*	644	360	*680*	1256
−68	*− 90*	−130	−3.9	*25*	77.0	15.0	*59*	138.2	33.9	*93*	199.4	177	*350*	662	366	*690*	1274
−62	*− 80*	−112	−3.3	*26*	78.8	15.6	*60*	140.0	34.4	*94*	201.2	182	*360*	680	371	*700*	1292
−57	*− 70*	− 94	−2.8	*27*	80.6	16.1	*61*	141.8	35.0	*95*	203.0	188	*370*	698	377	*710*	1310
−51	*− 60*	− 76	−2.2	*28*	82.4	16.7	*62*	143.6	35.6	*96*	204.8	193	*380*	716	382	*720*	1328
−46	*− 50*	− 58	−1.7	*29*	84.2	17.2	*63*	145.4	36.1	*97*	206.6	199	*390*	734	388	*730*	1346
−40	*− 40*	− 40	−1.1	*30*	86.0	17.8	*64*	147.2	36.7	*98*	208.4	204	*400*	752	393	*740*	1364
−34.4	*− 30*	− 22	− .6	*31*	87.8	18.3	*65*	149.0	37.2	*99*	210.2	210	*410*	770	399	*750*	1382
−28.9	*− 20*	− 4	0	*32*	89.6	18.9	*66*	150.8	37.8	*100*	212.0	216	*420*	788	404	*760*	1400
−23.3	*− 10*	14	0.6	*33*	91.4	19.4	*67*	152.6	38	*100*	212	221	*430*	806	410	*770*	1418
−17.8	*0*	32	1.1	*34*	93.2	20.0	*68*	154.4	43	*110*	230	227	*440*	824	416	*780*	1436
−17.2	*1*	33.8	1.7	*35*	95.0	20.6	*69*	156.2	49	*120*	248	232	*450*	842	421	*790*	1454
−16.7	*2*	35.6	2.2	*36*	96.8	21.1	*70*	158.0	54	*130*	266	238	*460*	860	427	*800*	1472
−16.1	*3*	37.4	2.8	*37*	98.6	21.7	*71*	159.8	60	*140*	284	243	*470*	878	432	*810*	1490
−15.6	*4*	39.2	3.3	*38*	100.4	22.2	*72*	161.6	66	*150*	302	249	*480*	896	438	*820*	1508
−15.0	*5*	41.0	3.9	*39*	102.2	22.8	*73*	163.4	71	*160*	320	254	*490*	914	443	*830*	1526
−14.4	*6*	42.8	4.4	*40*	104.0	23.3	*74*	165.2	77	*170*	338	260	*500*	932	449	*840*	1544
−13.9	*7*	44.6	5.0	*41*	105.8	23.9	*75*	167.0	82	*180*	356	266	*510*	950	454	*850*	1562
−13.3	*8*	46.4	5.6	*42*	107.6	24.4	*76*	168.8	88	*190*	374	271	*520*	968	460	*860*	1580
−12.8	*9*	48.2	6.1	*43*	109.4	25.0	*77*	170.6	93	*200*	392	277	*530*	986	466	*870*	1598
−12.2	*10*	50.0	6.7	*44*	111.2	25.6	*78*	172.4	99	*210*	410	282	*540*	1004	471	*880*	1616
−11.7	*11*	51.8	7.2	*45*	113.0	26.1	*79*	174.2	100	*212*	414	288	*550*	1022	477	*890*	1634
−11.1	*12*	53.6	7.8	*46*	114.8	26.7	*80*	176.0	104	*220*	428	293	*560*	1040	482	*900*	1652
−10.6	*13*	55.4	8.3	*47*	116.6	27.2	*81*	177.8	110	*230*	446	299	*570*	1058	488	*910*	1670
−10.0	*14*	57.2	8.9	*48*	118.4	27.8	*82*	179.6	116	*240*	464	304	*580*	1076	493	*920*	1688
− 9.4	*15*	59.0	9.4	*49*	120.2	28.3	*83*	181.4	121	*250*	482	310	*590*	1094	499	*930*	1706
− 8.9	*16*	60.8	10.0	*50*	122.0	28.9	*84*	183.2	127	*260*	500	316	*600*	1112	504	*940*	1724
− 8.3	*17*	62.6	10.6	*51*	123.8	29.4	*85*	185.0	132	*270*	518	321	*610*	1130	510	*950*	1742
− 7.8	*18*	64.4	11.1	*52*	125.6	30.0	*86*	186.8	138	*280*	536	327	*620*	1148	516	*960*	1760
− 7.2	*19*	66.2	11.7	*53*	127.4	30.6	*87*	188.6	143	*290*	554	332	*630*	1166	521	*970*	1778
− 6.7	*20*	68.0	12.2	*54*	129.2	31.1	*88*	190.4	149	*300*	572	338	*640*	1184	527	*980*	1796
− 6.1	*21*	69.8	12.8	*55*	131.0	31.7	*89*	192.2	154	*310*	590	343	*650*	1202	532	*990*	1814
− 5.6	*22*	71.6	13.3	*56*	132.8	32.2	*90*	194.0	160	*320*	608	349	*660*	1220	538	*1000*	1832
− 5.0	*23*	73.4	13.9	*57*	134.6	32.8	*91*	195.8	166	*330*	626	354	*670*	1238			

SOURCE: Reprinted by permission Fisher Scientific Company.

TABLE 16. RELATIVE HUMIDITY TABLE

To find the relative humidity, assume the reading of the dry-bulb is 90° and the wet-bulb is 85°; subtract the wet-bulb reading (85°) from the dry-bulb reading (90°), which gives a difference of 5°. Follow down the column headed (5°) and read across the table from dry-bulb reading (90°). We find the relative humidity is 81 per cent where the two lines intersect.

Temperature readings in degrees Fahrenheit. Relative humidity readings in per cent. Barometric pressure 29.92 inches

Temperature of dry bulb	Difference between wet- and dry-bulb thermometers, °F.																																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
60	94	89	83	78	73	68	63	58	53	48	44	39	34	30																										
70	95	90	85	81	76	72	68	64	59	56	51	47	43	40	37	33	29																							
80	95	91	87	83	79	75	71	68	64	61	57	54	50	47	44	41	38	35	32	29																				
90	96	92	88	85	81	77	74	71	67	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	25															
100	96	93	89	86	83	79	76	73	70	68	64	62	59	57	54	51	48	46	44	42	39	37	35	33	31	29	27													
102	96	93	89	86	83	80	77	74	71	69	65	62	59	57	54	52	49	47	45	43	40	38	36	34	32	30	28													
104	96	93	90	86	83	80	77	74	71	69	65	63	60	58	55	52	50	48	46	43	41	39	37	35	33	31	29	27												
106	96	93	90	87	83	80	77	74	72	69	66	63	60	58	56	53	51	48	46	44	42	40	38	36	34	32	30	28												
108	96	93	90	87	84	81	78	75	72	70	66	64	61	59	56	54	51	49	47	45	43	41	39	37	35	33	31	29	28											
110	96	93	90	87	84	81	78	75	72	70	67	64	62	60	57	55	52	50	48	46	44	41	39	37	36	34	32	30	28	27										
112	96	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	53	51	49	47	44	42	40	38	37	35	33	31	29	28										
114	97	93	90	87	84	81	78	75	73	71	68	65	63	61	58	56	53	51	49	47	45	43	41	39	37	35	34	32	30	28	27									
116	97	93	90	88	84	82	79	76	74	71	68	66	63	61	59	56	54	52	50	48	46	44	42	40	38	36	34	33	31	29	28									
118	97	93	91	88	85	82	79	76	74	71	68	66	64	62	59	57	54	53	51	49	46	44	42	41	39	37	35	34	32	30	29	27								
120	97	94	91	88	85	82	79	77	74	72	69	66	64	62	60	57	55	53	51	49	47	45	43	41	40	38	36	34	33	31	30	28	27							
122	97	94	91	88	85	82	79	77	75	72	69	67	65	63	60	58	56	54	52	50	48	46	44	42	40	38	37	35	33	32	30	29	27							
124	97	94	91	88	85	83	80	77	75	72	70	67	65	63	61	58	56	54	52	51	48	46	44	43	41	39	37	36	34	33	31	29	28	27						
126	97	94	91	88	86	83	80	78	75	73	70	68	65	64	61	59	57	55	53	51	49	47	45	43	42	40	38	37	35	33	32	30	29	28						
128	97	94	91	89	86	83	80	78	76	73	71	68	66	64	61	59	57	55	53	52	49	47	46	44	42	40	39	37	36	34	33	31	30	28	27					
130	97	94	91	89	86	83	80	78	76	73	71	68	66	64	62	60	58	56	54	52	50	48	46	44	43	41	40	38	36	35	33	32	30	29	28					
132	97	94	92	89	86	83	81	78	76	74	71	69	67	65	62	60	58	56	54	53	50	49	47	45	43	42	40	39	37	35	34	32	31	30	29	27				
134	97	94	92	89	86	84	81	79	76	74	71	69	67	65	63	61	59	57	55	53	51	49	47	46	44	42	41	39	38	36	35	33	31	31	29	28				
136	97	94	92	89	86	84	81	79	77	74	72	69	67	65	63	61	59	57	55	53	51	50	48	46	45	43	41	40	38	37	35	34	32	31	30	28	27			

Temperature of dry bulb	Difference between wet- and dry-bulb thermometers, °F.																																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
138	97	94	92	89	86	84	81	79	77	74	72	70	68	66	63	62	60	58	56	54	52	50	48	47	45	43	42	40	39	37	36	35	33	32	31	29	28	27		
140	97	94	92	89	87	84	81	79	77	75	72	70	68	66	64	62	60	58	56	54	52	51	49	47	46	44	42	41	39	38	36	35	34	33	31	30	28	27		
142	97	94	92	89	87	84	82	80	77	75	73	70	68	66	64	62	60	58	57	55	53	51	49	48	46	44	43	42	40	39	37	36	34	33	32	30	29	28	27	
144	97	95	92	89	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	53	52	50	48	47	45	44	42	41	39	38	36	35	34	32	31	30	29	27	
146	97	95	92	90	87	85	82	80	78	75	73	71	69	67	65	63	61	59	57	56	54	52	50	49	47	45	44	43	41	40	38	37	36	35	33	32	30	29	28	27
148	97	95	92	90	87	85	82	80	78	76	73	71	69	67	65	63	61	60	58	56	54	53	51	49	48	46	45	43	42	40	39	38	36	35	34	32	31	30	28	28
150	98	95	92	90	87	85	82	80	78	76	74	72	70	68	66	64	62	60	58	57	55	53	51	49	48	46	45	43	42	41	39	38	37	36	34	33	31	30	29	28
152	98	95	93	90	88	85	83	81	79	76	74	72	70	68	66	64	62	60	59	57	55	53	52	50	48	47	46	44	42	41	40	39	37	36	35	33	32	31	30	29
154	98	95	93	90	88	85	83	81	79	77	74	72	70	68	66	65	63	61	59	57	56	54	52	50	49	47	46	44	43	42	40	39	38	37	35	34	33	32	30	29
156	98	95	93	90	88	85	83	81	79	77	74	72	71	69	67	65	63	61	59	58	56	54	53	51	49	48	46	45	43	42	41	40	38	37	36	34	33	32	31	30
158	98	95	93	90	88	86	83	81	79	77	75	73	71	69	67	65	63	61	60	58	56	55	53	51	50	48	47	45	44	43	41	40	39	38	36	35	34	33	31	30
160	98	95	93	90	88	86	83	81	79	77	75	73	71	69	67	65	64	62	60	58	57	55	53	52	50	49	47	46	44	43	42	41	39	38	37	35	34	33	32	31
162	98	95	93	90	88	86	84	82	80	77	75	73	71	69	68	66	64	62	60	59	57	55	54	52	51	49	47	46	45	44	42	41	40	39	37	36	35	34	32	31
164	98	95	93	91	88	86	84	82	80	78	75	73	72	70	68	66	64	62	61	59	58	56	54	52	51	49	48	47	45	44	43	41	40	39	38	36	35	34	33	32
166	98	95	93	91	88	86	84	82	80	78	76	74	72	70	68	66	65	63	61	59	58	56	54	53	51	50	48	47	46	44	43	42	41	39	38	37	36	35	33	32
168	98	95	93	91	88	86	84	82	80	78	76	74	72	70	68	67	65	63	61	60	58	56	55	53	52	50	49	47	46	45	43	42	41	40	39	37	36	35	34	35
170	98	95	93	91	89	86	84	82	80	78	76	74	72	70	69	67	65	63	62	60	59	57	55	53	52	51	49	48	47	45	44	43	41	40	39	38	37	35	34	33
172	98	95	93	91	89	86	84	82	81	78	76	74	73	71	69	67	66	64	62	60	59	57	55	54	53	51	50	48	47	46	45	43	42	41	39	38	37	36	35	34
174	98	95	93	91	89	87	84	83	81	78	76	75	73	71	69	67	66	64	62	61	59	57	56	54	53	51	50	49	47	46	45	43	42	41	40	39	37	36	35	34
176	98	96	94	91	89	87	85	83	81	79	77	75	73	71	70	68	66	64	63	61	60	58	56	55	53	52	50	49	48	46	45	44	43	42	40	39	38	37	36	35
178	98	96	94	91	89	87	85	83	81	79	77	75	73	72	70	68	66	64	63	61	60	58	56	55	54	52	51	49	48	47	46	44	43	42	41	39	38	37	36	35
180	98	96	94	91	89	87	85	83	81	79	77	75	73	72	70	68	67	65	63	62	60	58	57	55	54	52	51	50	48	47	46	45	43	42	41	40	39	38	36	35
182	98	96	94	91	89	87	85	83	81	79	77	75	74	72	70	68	67	65	63	62	60	59	57	56	54	53	51	50	49	48	46	45	44	43	42	40	39	38	37	36
184	98	96	94	92	89	87	85	83	82	79	77	76	74	72	70	69	67	65	64	62	61	59	57	56	55	53	52	50	49	48	47	45	44	43	42	41	39	38	37	36
186	98	96	94	92	90	87	85	83	82	80	78	76	74	72	71	69	67	66	64	62	61	59	58	56	55	53	52	51	49	48	47	46	44	43	42	41	40	39	38	37
188	98	96	94	92	90	87	85	84	82	80	78	76	74	73	71	69	68	66	64	63	62	59	58	57	55	54	52	51	50	49	47	46	45	44	43	41	40	39	38	37
190	98	96	94	92	90	88	86	84	82	80	78	76	75	73	71	69	68	66	65	63	62	60	58	57	56	54	53	51	50	49	48	46	45	44	43	42	41	39	38	37
200	98	96	94	92	90	88	86	84	82	80	79	77	75	74	72	70	69	67	66	64	63	61	60	58	57	55	54	53	52	51	49	48	47	46	45	43	42	41	40	39

INDEX